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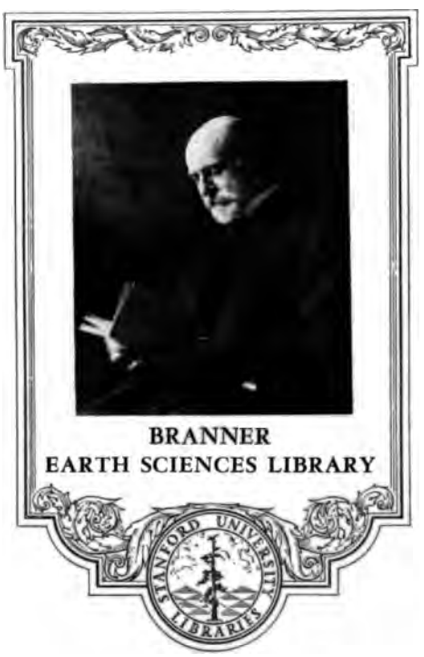
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UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

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# PRELIMINARY REPORT

ON THE

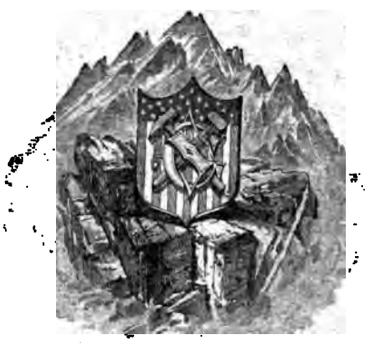
# KETCHIKAN MINING DISTRICT, ALASKA

WITH

## AN INTRODUCTORY SKETCH OF THE GEOLOGY OF SOUTHEASTERN ALASKA

BY

ALFRED HULSE BROOKS



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1902

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In the eastern part of the region also some topographic work had been done by the International Boundary Survey. These maps[a] were used as a basis for the geologic work, with such supplementary corrections and sketches as time and means permitted. Throughout the field and office work the writer has had the efficient aid of Mr. Corey C. Brayton.

The writer, in company with Mr. Brayton, reached Ketchikan on July 12. Several days were spent at this point in outfitting and organizing a party and in examining the geology of the vicinity. A 35-foot gasoline launch had been brought from Seattle, and on this the party of four lived and traveled during the progress of the work. They were fortunate in securing as pilot Mr. L. Andersen, whose long experience in the waters of southeastern Alaska made him invaluable on a coast which had not been charted in detail.

After leaving Ketchikan, the gold deposits of Helm Bay and Smuggler Cove, on Cleveland Peninsula, were the first which were examined. Thence the party encircled Revillagigedo Island, visiting Neets Bay, Bell Island, and Burroughs Bay. This trip was made for the purpose of determining the relation of the sedimentary beds to the Coast Range granite. The next stop was at the upper end of Thorne Arm, where the Sea Level claim and adjacent gold-bearing properties were examined. The party then proceeded to the head of George Inlet, making several stops to examine silver and lead deposits. The mining claims bordering Tongass Channel were visited on the way to Ketchikan, whence, after securing additional supplies and fuel, the party proceeded to the lower end of Gravina Island. At this point several days were spent in examining the copper deposits of Seal Bay and Dall Head.

On August 4, after crossing Clarence Strait, Niblack Anchorage was reached. During a stay of several days a hasty examination was made of the more important copper and gold claims of the vicinity. From this point a reconnaissance of Moira Sound was made, and on August 8 the party reached the head of North Arm. The examination of the mining claims in the vicinity of North Arm occupied the party until August 11. The 12th and 13th were spent in the gold-bearing region in the vicinity of Dolomi, Johnson Inlet. From this point the party proceeded to the head of the North Arm of Cholmondeley Sound, and thence made a trip across the portage and down Hetta Inlet to Copper Mountain, where a day was spent. On August 17 and 18 the properties on the South Arm of Cholmondeley were examined, and August 19 and 20 were spent in Kitkun Bay. From Kitkun Bay trips were made to various claims on Skowl Arm, and on August 24 Kasaan Bay was reached. The examination of the many mining properties in the vicinity of Kasaan Bay occupied the attention of the party from August 25 until September 4. During this time three days were spent in the Hollis gold-bearing region. After a brief visit to Tolstoi Bay to see the Iron Cap group of copper claims, the party returned to Ketchikan.

[a] Charts Nos. 8100 and 8050, U. S. Coast and Geodetic Survey.

## SKETCH OF THE GEOLOGY OF SOUTHEASTERN ALASKA.

### GEOGRAPHY.

The panhandle of Alaska, which extends southeastward from Mount St. Elias, is usually called southeastern Alaska. This coastal belt, with its contiguous islands, has an area of nearly 50,000 square miles. It is included between latitudes 54° 30′ and 60° 30′ and longitudes 130° and 141°. That portion which is more especially the subject of this sketch lies to the southeast of Cross Sound and Glacier Bay, and includes an area of about 20,000 square miles. Its position relative to other portions of the earth's surface can better be comprehended by the statement that Sitka, which is located on an island in the northern part of this belt, is on the same parallel of latitude as Edinburg, in Scotland.

Alaska is divisible into four geographic provinces, corresponding to and, broadly speaking, coextensive with those of western Canada and the United States. The westernmost of these includes a mountainous belt, which, in conformity to Major Powell's nomenclature,[a] may be called the Pacific Mountain system. East of this is the Plateau region, bounded to the east and north by the third province, which is formed by the northern and western extension of the Rocky Mountain system. East and north of the Rocky Mountains is the fourth province, comprising the Plains region. Southeastern Alaska falls entirely within the first of these provinces. The Pacific Mountain system in this region includes four important ranges, the Coast, St. Elias, Aleutian, and Alaskan ranges, whose axes are parallel to the coast, and numerous inferior transverse ranges. The Coast Range, the St. Elias Range, and the Aleutian Range lie adjacent to the coast, while the Alaskan Range is inland and forms the northern boundary of the system. The Aleutian and Alaskan ranges lie outside the region under discussion and will not be further considered.

The so-called Coast Range extends from near the boundary of Washington northward through British Columbia into southeastern Alaska. In British Columbia it has a width of about 100 miles, which decreases to the northward. Its peaks vary in altitude from 7,000 to 8,000 feet. Following the coast line for nearly 900 miles, it passes behind the St. Elias Range near the head of Lynn Canal. Beyond this point it decreases in altitude northward and gradually loses its distinctiveness, finally merging with the Interior Plateau. The Coast Range has no distinct crest line, but, as Drs. Dawson and Hayes have shown, is an irregular aggregate of mountains whose summits mark an elevated plateau and whose limits are often ill defined. Inland it locally merges with the Interior Plateau, and on the coast side it is not always well differentiated from the mountains of the Alexander Archipelago.

[a] Under "Pacific Mountains" Major Powell included ranges lying west of the Basin ranges in the United States. The term "Pacific Mountain system" is intended to include all of the mountains of North America which lie contiguous to the Pacific Ocean. (See Monographs Nat. Geog. Soc., Vol. I, 1896, pp. 96–100.)

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Westward from Cross Sound the St. Elias Range, which seems to be the extension of the mountainous Alexander Archipelago, forms the most prominent coastal feature of Alaska. Near Mount St. Elias the range has a width of about 100 miles, but it narrows down in both directions. Near Cross Sound the Fairweather group of mountains in the St. Elias Range reach altitudes of over 15,000 feet. Toward the west the range increases in height and complexity, culminating in Mounts St. Elias and Logan, 18,060 and 19,500 feet in height, respectively. The mountains of the Alexander Archipelago can not be said to form any well-defined range. On Baranof Island are mountains reaching altitudes of 3,000 to 4,000 feet. On Prince of Wales Island there are also many peaks which rise to this height, but they are more or less irregularly distributed. In general, these mountain groups trend in a northwest-southeast direction, parallel to the coast line and to the Coast Range. There are but few topographic data available in this region except the contour of the actual shore line.

The coast line of this part of Alaska is very irregular, the shore being marked by many deep embayments and islands. The shores are usually very abrupt and the deep water lies close to the land.

More than half of the land area of that portion of Alaska which lies southeast of Glacier Bay is included in the islands of the Alexander Archipelago. The largest of these are Chichagof, Baranof, Admiralty, Kupreanof, Kuiu, Prince of Wales, Etolin, and Revillagigedo, and there are many small ones. The longer axes of the larger islands roughly parallel the general trend of the coast of the mainland. The otherwise smooth coast lines of the islands are broken by numerous fiords, similar to those which penetrate deeply into the adjacent Coast Range. The islands are separated from each other and the mainland by deep and often very narrow waterways. Some of these, like Lynn Canal, penetrate far inland. An examination of the map, Pl. I, will show that these features have more or less of a parallel arrangement, and elsewhere attention will be drawn to the fact that the direction of these channels is consequent on structural lines in the bed rock.

In southeastern Alaska four rivers of considerable size, the Alsek, Chilkat, Taku, and Stikine, have their sources in the Interior Plateau region, and reach the sea after traversing the coastal ranges. The Chilkat flows through the depression which separates the northern extension of the Coast Range and the St. Elias Mountains.

The Alsek system includes a region of extremely varied topography. Its upper waters lie within the Yukon Plateau, and its valley has there been cut to a depth of 3,000 to 4,000 feet below the general level of the surrounding country. Its lower valley cuts entirely through the St. Elias Range, and there the relief must be many thousand feet, but accurate data are entirely lacking. The Alsek is said to be fed by numerous glaciers where it cuts the range. After leaving the mountains the Alsek spreads out into the broad delta called Dry Bay.

The Chilkat has its source in a broad depression which forms the divide between

it and the Alsek River. It has a southerly course and flows into Chilkat Inlet, an embayment of Lynn Canal. The valley walls of the Chilkat are characterized by many benches and terraces, which probably had a glacial origin. It is fed by numerous glaciers, which have their sources in the St. Elias Range to the southwest and in the Coast Range to the northeast.

The Taku River rises in the Plateau region, near the headwaters of the Teslin, it has a general southwesterly course, and is tributary to Taku Inlet. It also receives several glaciers where it traverses the Coast Range.

The Stikine River is the largest of the four. Its source lies far inland, in northern British Columbia, where its headwaters interlock with those of the Liard River. In its upper course it has a rather broad valley, incised to a depth of 3,000 to 4,000 feet in the plateau. Where it traverses the Coast Range the valley is narrower and the walls are more abrupt. It here receives many tributary glaciers. At its mouth it has a broad flood plain.

On the mainland of southeastern Alaska there are many minor streams which have their sources within the Coast Range.

The drainage of the islands of the Alexander Archipelago is usually carried to the sea by small streams. The lack of topographic maps makes it impossible to describe them in any detail.

## BED-ROCK GEOLOGY.

### INTRODUCTION.

So little is known of the bed-rock geology of the panhandle of Alaska, extending southeastward from Yakutat Bay, that it has seemed to the writer worth while to correlate the data available and to present some tentative conclusions. A few small areas in this region have been studied in more or less detail, and many facts have been gathered, but practically no attempt has been made to bring them together. The studies of the Canadian geologists, especially those of Dr. Dawson near the international boundary and in British Columbia, have contributed to the deciphering of the stratigraphic succession and to the pointing out of some of the more important structural features.

Many of the early exploring expeditions which visited this coast included naturalists who made collections and in their reports made mention of some of the geologic features of the region. These observations have been collected by Dr. Dall,[a] to whose report the reader is referred for details.

In 1863 Mr. William P. Blake,[b] on his return from Japan, visited Sitka and joined a Russian expedition which explored the Lower Stikine. Mr. T. A. Blake made observations on the geology and mineral resources of southeastern Alaska,[c]

[a] Coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, Pt. I, 1896, pp. 835–837.

[b] Geographical notes upon Russian America and the Stikine River: House Ex. Doc. No. 177, Pt. 2, Fortieth Congress, second session.

[c] Topographical and geological features of the northwest coast of America: Am. Jour. Sci., 2d series, Vol. XLV, 1868, pp. 242–247. Geology of Alaska Territory: U. S. Coast Survey Report for 1867, pp. 281–290.

River. In the following year[a] the writer went inland by the Dalton-trail route and obtained some geologic notes along the Chilkat and Klehini rivers.

There have also been brief reports in the technical journals on some of the mining districts. The Juneau district has been described by G. W. Garside,[b] and the Ketchikan mining region by W. T. Brewer,[c] and also by an anonymous writer.[d]

## GENERAL DESCRIPTION.

While but few of the details of the geology of southeastern Alaska are known, and even the general succession of beds is very much in doubt, yet the distribution of certain lithologic types is fairly well established. The rocks, in general, trend in a northwest-southeast direction, parallel to the coast line. There are certain lithologic types occurring as belts running parallel to this strike, which seem to persist with somewhat remarkable uniformity from Dixon Entrance to Lynn Canal and Icy Strait. These belts, together with some rather fragmentary paleontologic evidence, have been used as the basis for the accompanying sketch map. In the compilation of this map the writer, who is familiar with only a part of the region, has had to make very liberal use of the results of previous workers. Such a compilation must almost of necessity contain errors even were the region well known, but when it is considered that much of the region is hardly explored an additional source of error appears. It is believed, however, that the advantages of bringing the information together in graphic form more than counterbalances the objection to publishing a map which must contain many errors and omissions. The aim has been to represent chiefly the distribution of certain lithologic types on the geologic map, but this has led to a certain amount of correlation.

The granitic rocks of the Coast Range form the best defined of the zones of lithologic unity. The granite is intrusive and occurs in other parts of the region in smaller areas. To the east of the Coast Range is a series of sediments, probably chiefly of Paleozoic age. These are in turn overlain unconformably by younger sediments, chiefly of Mesozoic age, containing considerable volcanic material. Adjacent to the granite of the Coast Range on the west is a belt of argillites, with some limestones of undetermined age, containing many greenstone intrusives. This series is considerably metamorphosed. To the west of the argillites blue limestones, but little altered and containing Devonian fossils, have been found at a number of localities. The westernmost islands of the Alexander Archipelago are chiefly made up of a series of white crystalline limestones and phyllites, which contain many greenstone intrusives. These rocks occupy considerable areas in Prince of Wales, Baranof, Chichagof, and Admiralty islands, and have been traced northward to Glacier Bay on the mainland.

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[a] Reconnaissance from Pyramid Harbor to Eagle City, Alaska. Twenty-first Ann. Rept. U. S. Geol. Survey, Pt. II, 1900, pp. 331–392.

[b] The mineral resources of southeast Alaska. Trans. Am. Inst. Min. Eng., Vol. XX, 1892-93, pp. 815–823.

[c] The Ketchikan mining district, Alaska. Eng. Min. Jour., Vol. LXXII, 1901, pp. 649–652.

[d] Min. Sci. Press, September 7, 1901, Vol. LXXXIII, pp. 98–101.

These five belts—the white limestone and phyllite, the blue limestone, the argillites to the west of the Coast Range granite, and the Paleozoic and Mesozoic to the east—form the country rock of the larger part of this province. There are also Tertiary sediments, volcanic rocks, and various types of intrusives in this region.

### PALEOZOIC SEDIMENTS.

The older sediments west of the Coast Range have been differentiated into three groups, of which two are Paleozoic and one is probably in part Paleozoic and in part Mesozoic. The corresponding beds east of the Coast Range are all grouped together as Paleozoic, for it is impossible to differentiate them on the facts now available.

The oldest beds in which fossils have been found are the limestones outcropping on the shores of Glacier Bay. This limestone, which Professors Reid and Cushing[a] describe as gray or blue in color, in places has been changed to a white marble. Professor Cushing found a few fossils in this limestone at Drake Island which were examined by Prof. H. S. Williams and determined to be Paleozoic. Later, on the evidence presented by these fossils, and particularly that of a coral collected from the Dirt Glacier by Prof. J. J. Stevenson, these limestones were assigned to the Carboniferous.[b] It will be shown below that the latter fossil is from an entirely different horizon. Through the kindness of Professor Williams, the Drake Island material was submitted to Mr. Charles Schuchert, to whom the writer is indebted for the following report:

"I have examined the Drake Island material and find a large *Leperditia* of the *L. baltica* group; *Megalomus* sp. undet., sections of a very large species very similar to *M. canadensis;* and *Hormotoma* sections, like several found in the Guelph of Ontario.

"The fossil on which one can depend for age determination is the *Leperditia.* These large species of *Leperditia* cease with the basal beds of the American Devonian (Lower Pentamerus-Coeymans), but their greatest abundance is in the Wenlock and Dudley horizons of Europe. The Glacier Bay species is unmistakably related to the *L. baltica* of the Upper Silurian. Further, it is not related to the large Lower Silurian forms of the *L. fabulites* group, and this is again shown by the presence of very large bivalve shells which I take to be of the genus *Megalomus*, a fossil so characteristic of the late Upper Silurian. Even if the large shells are not *Megalomus*, these *Leperditias* alone prove that the limestone can not be younger than late Upper Silurian. It is true that the genus *Leperditia* is stated to occur as late as Lower Carboniferous time (*L. carbonaria* Hall, *L. nicklesi* Ulrich), but all the Devonian and Carboniferous species are minute forms, and if they do not belong to other genera, which is not improbable, they certainly can not be included in the *L. baltica* group of *Leperditia.*

"The coral identified as *Lonsdaleia* comes from another locality (Dirt Glacier) more than 15 miles away, and can not be included in the Drake Island fauna. To this locality one should for the present restrict the type section for the 'Glacier Bay limestone,' for the reasons above given and for the further one that the coral was not found in situ."

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[a] Nat. Geog. Mag., Vol. IV, p. 59; Sixteenth Ann. Rept. U. S. Geol. Survey, Pt. I, p. 433.
[b] Sixteenth Ann. Rept. U. S. Geol. Survey, Pt. I, p. 434.

Reid and Cushing found an argillite series underlying the limestone conformably. Both of these formations are closely folded. Their thickness was not determined, but it is probably several thousand feet. Intrusives of a dioritic character are plentiful in the Glacier Bay region, and show evidence of having suffered some deformation.

White limestones were observed by the writer outcropping along Peril Strait on Baranof and Chichagof islands. They are intimately associated with argillites, and they are all rather closely folded. Greenstone intrusives are also common in these beds. They are in every way similar to those described from Glacier Bay, except that they are probably more metamorphosed. The phyllites of this series are well exposed on Rodman Bay, where they are finely plicated. A white crystalline limestone occurs at the southeastern end of Chichagof Island, near Sitkoh Bay, and again at Kootznahoo, on Admiralty Island. Large areas of white crystalline limestone are exposed at the upper end of Prince of Wales Island, where a marble quarry is located. In the southern part of Prince of Wales Island are white limestones and phyllites which have been grouped together as the Wales series.[a]

The above facts go to show that there is more or less of a continuous belt of white limestones and phyllites extending through the westernmost islands of the Alexander Archipelago to Glacier Bay. At Glacier Bay these beds have been determined to be of Upper Silurian age. The series is, therefore, provisionally assigned to the Lower Paleozoic. This series has commercial importance, as in its more crystalline form it is known to carry gold and copper deposits.

Reference has already been made to a coral which was found on the moraine of Dirt Glacier by Professor Stevenson, who describes the locality as follows:[b]

"The 'Dirt Glacier,' or first eastern tributary of the Muir, must head up against an outcrop of this limestone, for one of the passengers on our vessel picked up a form like *Acervularia*, which, taken in connection with some *Leperditia* obtained by Mr. Cushing in 1890 [Drake Island], tends to show that the limestone [of Glacier Bay] is not younger than Middle Devonian."

Through the courtesy of Professor Williams, Mr. Schuchert was enabled to examine the coral secured by Professor Stevenson, and he reports as follows:

"Later this coral was sent to Professor Williams, and Cushing reports that he identified it as a *Lonsdaleia*, 'and regards it as demonstrative of the Carboniferous age of the horizon whence it came.'

"I agree with Stevenson that the coral in question is an *Acervularia*, since it has *no columella*, as is demanded for species of *Lonsdaleia*. It is a species near *A. davidsoni*, a coral characteristic of the Middle Devonian of the Mississippi Valley. It may prove to be a new species when sections are made. The genus *Acervularia*, however, is unknown above the Devonian. Another *Acervularia* is known from the Mackenzie River country (*Cyathophyllum arcticum* Meek), so that the genus may be expected to turn up elsewhere in the far North.

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[a] See pp. 41–42, and Pl. II.

[b] Scottish Geog. Mag., Vol. IX, 1893, p. 70.

"Since *Acervularia* of the *A. davidsoni* type is so characteristic of the Middle Devonian, it seems safe to assume that beds of this age occur in the Glacier Bay region, and that it is the same general horizon discovered the past summer by Mr. Brooks at Long Island, Kasaan Bay, and Prince of Wales Island."

Mr. Schuchert's determination shows that this coral is from a bed which is an entirely different horizon from the limestones at Drake Island, which he determined as Silurian. In view of this fact it is interesting to note what Professor Cushing says in regard to the limestone beds from which the coral must have come:

"However, further light has been shed upon this point by the discovery, chronicled by Professor Stevenson, of a piece of fossil coral on one of the moraines of the Dirt Glacier. A single one of these peaks amid which the Dirt Glacier has its source is capped by the limestone; otherwise the drainage basin of this glacier lies entirely in argillites or eruptive rocks, so that the locality whence this coral was derived is pointed out beyond question."[a]

All this evidence points to the conclusion that there is a younger limstone in the Glacier Bay region, which is of Devonian age. This limestone has not been identified at any other locality in the vicinity. In the southern islands of the archipelago, however, Devonian beds have been found at several places. Mr. Schuchert identified as Devonian some fossils[b] contained in a white crystalline limestone collected at Saginaw Bay, Kuiu Island, by Mr. Brightman. It is interesting to note that some fragments of sandstone from this same locality contain Lower Carboniferous fossils. This is the only locality in southeastern Alaska where this horizon has been identified.

In the Ketchikan district, as will be shown below, Middle Devonian fossils were found at Long Island, Kasaan Bay, and at Vallenar Bay, Gravina Island. At these localities the evidence goes to show that the Devonian rests unconformably on the older beds. These Devonian limestones, together with some associated slates, have been grouped together as the Vallenar series.

The presence of Devonian fossils in these widely separated localities goes to show that beds of this period are probably well represented in southeastern Alaska. At the Prince of Wales Island locality the Devonian beds are almost entirely unaltered, and this rather unsafe criterion has been used to differentiate them from the older white crystalline limestone series. When more detailed examinations are made it may be found that some of the crystalline limestones are of Devonian age. On the map the Devonian limestone and associated beds are grouped together as Upper Paleozoic.

The Upper and Lower Paleozoic beds east of the Coast Range have not been differentiated, as they have been to the west, and they are therefore grouped together on the accompanying map. Dawson's work has thrown much light on the general

[a] Trans. New York Acad. Sci., Vol. XV, p. 26.

[b] Report on Paleozoic fossils from Alaska, by Charles Schuchert, in Appendix II of Coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, Pt. I, p. 902.

relations of the Paleozoic rocks east of the Coast Range, and the following is quoted from his description:[a]

"East and northeast of the Coast Ranges the interior region traversed is, for the most part, floored by Paleozoic rocks of very varied appearance, and probably referable to several of the main subdivisions of the geological scale. In so far as the information obtained in the region here in question enables conclusions on the subject to be formed, the lowest part of the rocks (1) consists of greenish and gray schists, generally feldspathic or hornblendic, but often quartzose and including distinctly micaceous and talcose schists, with some bands of limestone, the lithological character of this subdivision being exceedingly varied. Apparently overlying these are (2) gray and blackish often lustrous and sometimes more or less micaceous calc-schists and quartzites, including beds of limestone of moderate thickness, which are often more or less dolomitic. These are associated with, or pass up into (3) black argillites or argillite-schists, also containing thin beds of limestone, which, at one locality on the Dease, have afforded a small number of graptolites of Cambro-Silurian age. Next above these is a series (4) consisting chiefly of massive limestones, generally of gray or blue-gray color where unaltered, but often locally changed into white or variegated crystalline marbles. These are closely associated with quartzites, which usually show the peculiar fine-grained cherty character of those of the typical Câche Creek series on the Fraser and Thompson rivers. The thickness of this subdivision can not (any more than that of those previously mentioned) be stated with precision, but that of the limestones alone must be several thousand feet in some places. On the Dease, on the Frances, and again on Tagish Lake fossils of Carboniferous age, including more particularly a species of *Fusulina*, have been detected in some beds of this limestone series, probably belonging to its upper portion. Forms of the genus *Fusulina* are characteristic in certain zones of the Carboniferous limestone in California. They have been found by the writer in a number of places in British Columbia, which, with the discoveries here reported on, occur at intervals along a belt of country to the northeast of the Coast Ranges for a distance of over 800 miles. The limestone last mentioned appears to be conformably followed or even in part interbedded with (5) a great mass of more or less evidently stratified rocks of volcanic origin, comprising amygdaloids, agglomerates, and other more massive materials, which apparently represent old lava-flows. All these are highly altered, so much so that in some cases their original physical character is scarcely demonstrable, while they have suffered changes also in constitution, having been converted for the most part into diabases.

"Analogy with the southern portions of British Columbia which I have examined leads me to believe that the greater part of these volcanic materials are also to be classed as of Carboniferous age, but it is quite probable that here, as to the south, they comprise as well rocks of similar appearance which are of Triassic age, but which we are at present unable to separate from them. This is further rendered probable by the occurrence in certain black argillites at Glenora, on the Stikine, of Triassic fossils and by the discovery by Mr. McConnell of fossils of this age on the Lower Liard River, some distance to the east of the region covered by this report."

A comparison of this succession with that found on the west side of the range suggests certain correlations. The black argillites [illegible] and heavy limestone (4) seem

[a] Geol. Sur. Can., Summ. Rep. 1887, p. 1B.

The Unuk is the next river which gives a cross section of this region, but unfortunately its geology has not been studied. Prospectors report black slates with some limestone beds lying close to the Coast Range granite.

Along the Skeena River Dawson[a] found black and gray mica-schist immediately east of the Coast Range, and then a belt of massive gray limestone which in general appearance corresponds to that found to the north. No fossils were found in this region, but it seems probable that this limestone is the same that has been described in the region to the north.

These facts go to show that there is a belt of Paleozoic rocks lying east of the Coast Range granite, stretching northwestward in British Columbia and Alaska close to the international boundary and to the east of it. These rocks include sediments of various descriptions, but are predominantly calcareous. Such paleontologic evidence as has been obtained points toward the conclusion that these Paleozoic beds range from Silurian or older to Carboniferous. They are cut by igneous rocks of various descriptions, only a few of which are represented on the accompanying geologic map.

### ARGILLITES.

Immediately west of the Coast Range granite a belt of argillites, containing some arenaceous beds and intruded by many masses of greenstone, has been traced northwestward from Dixon Entrance to Lynn Canal. The rocks making up this belt are schistose throughout, and the argillites are often highly graphitic. They are well developed in the vicinity of Juneau and Taku Inlet, and were also observed to outcrop along the lower regions of the Chilkat River and at various localities to the south. In the Ketchikan region these rocks, which have been called the Ketchikan schists, occupy a broad belt upon the western side of Revillagigedo Island. The relation of these beds to the Paleozoics lying west of them is undetermined, but in the Ketchikan region there has probably been faulting along the line of contact. Farther north no opportunity was presented for studying the boundary. Some limestones which are associated with the argillites are believed to be an integral part of the series, though they may be portions of an older series exposed by erosion. The only fossils found in these rocks were some crinoid stems from George Inlet in the Ketchikan district, which have little determinative value.

The folding and alteration of the argillite series is probably due to the intrusion of the Coast Range granite.[b] The series has usually been regarded as of Mesozoic age, though there is no definite proof of this, except that its geographic distribution suggests that it overlies the Upper Paleozoic series, but this may be due to faulting. Portions of the series, including the associated greenstone-schists, are often heavily mineralized, and often carry commercial gold ores.

[a] Rept. on an exploration from Port Simpson on the Pacific Coast to Edmonton on the Saskatchewan, embracing a portion of the northern part of British Columbia and the Peace River country, by Geo. M. Dawson: Geol. Nat. Hist. Survey Canada, 1879-80, pp. 1-177 B.

[b] Geol. Nat. Hist. Survey Canada, new series, Vol. III, Pt. I, 1887-88, p. 32 B.

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[b] Geol. Nat. Hist. Survey Canada, new series, Vol. III, Pt. I, 1887–88, p. 32 B.

### MESOZOIC SEDIMENTS.

The eastern belt of Paleozoic rocks is overlain unconformably by a sedimentary series. This series at its base is usually a conglomerate, and is made up of sandstones, arkoses, tuffs, and quartzites. It is typically developed at the upper end of Marsh Lake, where it includes many beds of volcanic tuff. At this locality the basal member, as determined by the writer, is a conglomerate whose pebbles are derived from the Upper Paleozoic rocks. Mr. Gwillim[a] has mapped the region lying between Marsh Lake and Atlin Lake, and finds a considerable development of these rocks. He is inclined to assign them to the Cretaceous; but Dr. Stanton, in a personal letter, says: "I have recently seen a few fragmentary fossils collected by Mr. Gwillim in the Atlin Lake region, and they seem to be of early Jurassic age."

In the Taku[b] section this horizon is represented by conglomerates whose pebbles are derived from Upper Paleozoic limestones. In the Stikine River section Dawson[c] also found a conglomerate series which he provisionally assigned to the Mesozoic. Dr. Dawson[d] reports some Jurassic fossils from the vicinity of Telegraph Creek. On the Skeena River Dawson[e] found Mesozoic fossils associated with gray argillites and sandstones containing impure coal.

The above facts point to the conclusion that the eastern belt of Paleozoic rocks is overlain by a clastic series, the basal member of which is a conglomerate usually derived from the underlying beds. The age of the series is Mesozoic, and in part at least Jurassic. It probably does not occur as a continuous belt, but rather in isolated areas. Gwillim[f] reports its thickness as 5,000 feet in the vicinity of Atlin Lake.

Still farther to the east and beyond the area under discussion Dawson[g] found fossiliferous Cretaceous beds at many localities on the Lewes and Pelly rivers. These now occur as gently folded beds in isolated areas.

On the western side of the Coast Range the Mesozoic rocks have nowhere been positively identified. At a few localities, however, heavy conglomerates were found overlying unconformably what are believed to be Paleozoic beds. Such an occurrence was found at the southern end of Gravina Island, in the Ketchikan district, where the conglomerates are overlain by black schists, and the whole series has been called the Gravina series. Mr. Schrader reports a heavy conglomerate at Hunter Bay, on the southern end of Prince of Wales Island. Conglomerates are also reported by prospectors at Union Bay, on the northern side of the Cleveland Peninsula. When the geology of southeastern Alaska is studied in greater detail, no doubt other localities of this horizon will be found. Broadly considered, this conglomerate is probably equivalent to that found at the base of the Mesozoic series on the eastern side of the range.

[a] Summary Report of the Geological Survey Department for the year 1900, Ottawa, 1901.
[b] Nat. Geog. Mag., Vol. IV, p. 138. Also from unpublished notes by Dr. Hayes.
[c] Geol. Nat. Hist. Survey Canada, 1887-88, p. 57 B.
[d] Op. cit., p. 56.
[e] Geol. Nat. Hist. Survey Canada, 1879-80, p. 102.
[f] Summary Report of the Geological Survey Department for the year 1900.
[g] Geol. Nat. Hist. Survey Canada, new series, Vol. III, Pt. I, 1887-88, Sec. B.

### TERTIARY SEDIMENTS.

On the accompanying map a number of areas of Tertiary sediments are represented. These have been noted by prospectors and others because they sometimes carry workable coal beds. They consist of conglomerates, sandstones, and shales, usually slightly indurated and only gently folded. They have been studied in some detail by Dall,[a] who assigned them to the Kenai division of the Oligocene. At Lituya Bay the Kenai beds are overlain by Astoria beds (Miocene).

At Sitka some highly feldspathic sandstones were observed, whose stratigraphic position was not determined. These were described by Becker[b] as pyroclastic diorites. In thin section they show many minerals derived from crystalline rocks. In the field they are sometimes massive, but more often thin bedded. Their stratigraphic position has not been determined, but they may provisionally be assigned to the Tertiary.

### IGNEOUS ROCKS.

The granite of the Coast Range forms the best-defined belt of igneous rock in the region. It extends northward from British Columbia throughout southeastern Alaska and crosses the international boundary again northwest of Chilkoot Pass. The granite usually contains hornblende and biotite, but has various local phases. It is typically massive, but frequently contains shear zones. In places it has been altered to a gneiss. The gneissoid phases seem to be more typical in the southern part of the belt, in the Ketchikan region, than in the north. Dawson has suggested that the gneissoid phases might be of Archean age.

In the section exposed along White Pass, as determined by the writer, the granite is entirely massive except for a few very narrow shear zones. It is frequently cut by dikes, usually of a dioritic or diabasic character. Rhyolitic and andesitic rocks were also observed in the vicinity of Skagway. The intrusive character of the granite has been proved by Dr. Dawson and others, and is well shown in the Ketchikan region along its contact with the argillaceous schist. Here belts of granite and schist alternate irregularly.

East of the Coast Range there are a number of extensive areas of granitic rocks, apparently belonging to the same age of intrusion as those of the Coast Range. To the west of the mountains smaller granite stocks are not uncommon.

Greenstones are the most widely distributed of the igneous rocks of the region. This term is made to include various igneous rocks of a rather basic character and of varied composition. The oldest intrusion seems to have taken place in early Paleozoic time and was of a diabasic nature. These older greenstones are usually schistose. Diorites and quartz-diorites are both massive and schistose. Among the less common types are gabbros, pyroxenites, and amphibolites. The older greenstones are usually much altered and made up chiefly of secondary minerals. In the Ketch-

[a] Coal and lignite of Alaska: Seventeenth Ann. Rept. U. S. Geol. Survey, Pt. I, pp. 763–908.
[b] Gold fields of southern Alaska: Eighteenth Ann. Rept. U. S. Geol. Survey, Pt. III, p. 43.

ikan district the diabases form the latest intrusions. Syenites have been found at a number of localities, notably at the Treadwell mine, near Juneau.

In this connection reference must be made to the effusive rock of the Ketchikan district, where there are large developments of andesitic and rhyolitic rocks, believed to be of Mesozoic age. Basalts and rhyolites occur in isolated patches in this district. A few of the larger areas east of the Coast Range are shown on the map. The more recent volcanic phenomena, so far as known, are limited to Mount Edgecumbe, a volcano on Kruzof Island, just west of Sitka.

## CORRELATION.

The stratigraphy of the regions lying adjacent to the province under discussion is too imperfectly known to enable correlations to be made with confidence. It will be of interest, however, to draw attention to certain analogies of stratigraphic succession and lithologic character. This is especially true of the field to the south, where the Canadian geologists have done some more or less detailed mapping.

In a previous report[a] the writer grouped the Carboniferous and Devonian beds of the Upper White and Tanana rivers together under the name Nutzotin series. This Nutzotin series would in a measure correspond to the subdivision called Upper Paleozoic on the accompanying map, but would probably also embrace a part at least of the argillites which lie adjacent to the Coast Range. In the report cited the limestones of Glacier Bay were all put in the Nutzotin, as they were then believed to be Carboniferous. In the same report the pre-Devonian sediments were grouped together as the Kotlo series, which would include the rocks of the Lower Paleozoic as defined in this report. As in southeastern Alaska, the two series are separated by an unconformity, and there are, broadly speaking, certain lithologic similarities in the rocks of the two regions.

In the Copper River district Schrader and Spencer[b] have described two formations which probably fall in the Upper Paleozoic. These are the Chitistone limestone, believed to be of Carboniferous age, and the underlying Nikolai greenstone. This limestone can be provisionally correlated with the Upper Paleozoic beds of southeastern Alaska. The subdivision made by Schrader and Spencer of the beds below this limestone finds but little analogy in the older sediments of the region under discussion.

The comparison of the Mesozoic beds of the Copper River region and of southeastern Alaska allows of certain tentative correlations. The Kennicott formation, occurring in the Copper River region, is generally of a sandy nature. It rests unconformably upon the upturned Paleozoic and Triassic strata, and contains fossils which prove its age to be Jura-Cretaceous, so that there are both paleontologic and structural grounds for correlating it with the recognized Mesozoic formations of southeastern Alaska. As regards the Lower Mesozoic rocks, the Triassic is well developed in the

[a] A reconnaissance from Pyramid Harbor to Eagle City: Twenty-first Ann. Rept. U. S. Geol. Survey, Pt. II, p. 359.

[b] Geology and mineral resources of the Copper River district, Alaska; a royal octavo pamphlet published by the United States Geological Survey in 1901 by authority of a joint resolution of Congress.

Copper River district, while in the southern region it has not been differentiated, although strata of this age may be, and probably are, included in the rocks which have been grouped either with the Upper Paleozoic Vallenar series or with the Ketchikan series, to which no age has been assigned.

The Tertiary sediments of southeastern Alaska are chiefly equivalent to the Kenai series, which has been identified in many localities in Alaska.

Dawson's last investigation[a] on the geology of this northern region is embodied in a report on the Kamloops district in southern British Columbia. This work was done in much more detail than any which preceded,[b] and resulted in a definite determination of the stratigraphic succession of all the formations involved.

The Kamloops region is too distant from the province under discussion to make correlations possible at present, but it is interesting to note that the Cambrian period is represented by beds aggregating a thickness of 40,000 feet. It seems probable that some of the Lower Paleozoic beds of southeastern Alaska may eventually be found to be of Cambrian age. The absence of Silurian and Devonian in the Kamloops region is noteworthy in comparison with the southeastern Alaskan section. Dawson finds definite evidence of the existence of pre-Cambrian rocks in this southern district.

In describing the geology of the Queen Charlotte Islands, Dawson[c] groups the Triassic and Carboniferous beds together, and states that these are unconformably overlain by Cretaceous rocks. After the close of the Triassic, folding took place, and it was probably during this general period that the great granitic intrusions occurred. From the descriptions of Dawson these Triassic and Carboniferous rocks are believed to show a striking analogy to the metamorphic argillites which lie adjacent to the Coast Range granites in southeastern Alaska. Dawson finds a large amount of volcanic material in the southern part of Vancouver Island in a series of rocks which he believes to belong to the Carboniferous. These volcanic effusives seem to have the same stratigraphic position as the Kasaan greenstones of southeastern Alaska, which have been provisionally assigned to the Mesozoic and probably belong to its lower portion.

The Mesozoic sedimentary rocks in the province under discussion would seem to correspond to the Cretaceous of the Queen Charlotte Islands, both in stratigraphic position and in lithologic character. Dawson notes a period of folding which succeeded the deposition of the Cretaceous. The Tertiary rocks described by him are chiefly volcanic, and are provisionally assigned to the Miocene.

On the Lower Skeena River and in the vicinity of Port Simpson Dawson found a metamorphic series made up of mica-schists and some limestones closely associated with gneisses. These would seem to be the southern extension of the Ketchikan

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[a] Report on the area of the Kamloops map sheet, British Columbia: Geol. Nat. Hist. Survey Canada, new series, Vol. VII, 1894.

[b] Dawson summarized the results of his twenty-five years of investigation of northwestern America in a presidential address to the Geological Society of America, entitled, Geological record of the Rocky Mountain region in Canada. Bull. Geol. Soc. Am., Vol. XII, 1901, pp. 57-92.

[c] Report on the Queen Charlotte Islands: Geol. Nat. Hist. Survey Canada, 1880, p. 45 B.

series, which is part of the belt of argillites that lies adjacent to the granite of the Coast Range throughout southeastern Alaska.

## DYNAMIC HISTORY.

The history of the deformation of the rocks of the region is complex, and has not yet been worked out. In the western belt of Lower Paleozoic beds the strata are intensely metamorphosed and deformed. To the east, in the Upper Paleozoic beds, there has been little dynamic action, while still farther to the east, in the belt of argillites, the metamorphic action has again been intense. To the east of the Coast Range the Paleozoic rocks have all suffered about the same degree of alteration, with the exception of those which lie immediately adjacent to the intrusive granites. It is evident that the observed metamorphism has been of two kinds, assignable to different causes—the regional metamorphism, which is due to deformation, and the contact metamorphism, which has been brought about by the intrusion of igneous rocks.

The phenomena of contact metamorphism are commonly regarded as confined to chemical effects produced by the heat and accompanying gases of igneous intrusions, but many cases are on record where the mechanical effect caused by the pressure of the invading rock has been of great importance. Such is the case in the vicinity of the granite masses of the Coast Range, where the mechanical alteration of the rocks is quite comparable to the regional metamorphism noted in neighboring localities; and, since the intrusion occurred after the greatest regional disturbance, the effects of the latter have been to a certain extent obscured by the former.

There are three zones in the region which are marked by more or less intense metamorphism. One includes the rocks of the Lower Paleozoic, extending through the western group of the Alexander Archipelago, while the other two lie on either side and adjacent to the granite of the Coast Range. The two westernmost of these zones, in the southern part of the region at least, are separated by a belt of Upper Paleozoic beds, which are folded, but only slightly indurated, while the Coast Range granite separates the two eastern zones.

In the western belt the sediments are intensely folded and plicated and are generally metamorphosed to such an extent that the limestones appear in the form of marble and the argillaceous strata as phyllites. The broad structural lines are in general parallel to the axis of the belt—that is, northwest and southeast—but the axes of minor folds are extremely variable in direction.

The period of mountain building during which these rocks were crushed and metamorphosed is the earliest of which we have any tangible record in southeastern Alaska, and in the Ketchikan district its date can be definitely recognized as pre-Devonian. It was during this epoch that the injection of the igneous rocks included under the designation "greenstone" commenced, though later intrusions of similar basic rocks are known to have occurred, as shown by the relatively massive character of certain of the greenstones when compared with others which are highly sheared.

In the southern part of the province it will be shown that Paleozoic sedimentation was interrupted by mountain building, and also that a period of erosion ensued, probably in early Devonian times. The Devonian beds are much less altered than those of the Lower Paleozoic, and the folding which they exhibit is of a broad, open type. Tracing these Devonian beds eastward, they are found to become metamorphosed as the zone of the Coast Range intrusives is approached.

The alteration observed in the two eastern zones adjacent to the intrusive granite belt of the Coast Range may be assigned, in part at least, to contact metamorphism. On the west side of the range most of the rocks are greatly altered argillites, and to the east of the range there is a succession of sediments whose basal members are also considerably altered. This metamorphism is in part plainly due to igneous contact, but must in part be assigned to the mechanical stress brought about by the intrusion of the granite. The intrusion of the granite has been shown to be Mesozoic, and probably post-Triassic. The evidence of contact metamorphism is the presence of minerals such as garnet and micas, which are developed in a limited contact zone. Mechanical metamorphism evinces itself in the development of shear zones, and of foliation as the granite mass is approached.

During Mesozoic times, and after the injection of the granite, large extrusions of volcanic rocks took place. These rocks, as well as the granite, were subsequently somewhat subjected to deformation, which was most intense along the axis of the Coast Range, where the granites were in part changed to gneisses and mica-schists. Subsequently another intrusion of igneous rock took place, which, though widely distributed, was not great in bulk. This epoch is represented by the large number of dikes, usually quite massive, which are found in different parts of the region. Deformational movements since Kenai time have been only of minor importance, as shown by the very gentle folding found in the Tertiary beds. So far as known, there is absolutely no evidence of a southern extension of the post-Tertiary disturbance which Russell[a] noted in the Mount St. Elias region. The most recent evidences of dynamic activity are the volcanic rocks of Mount Edgecumbe and some basalt flows which have been found in various parts of the region.

One of the effects of crustal movements has been the production of lines of weakness in the rocks, which have been sought out by erosive agencies. These structural lines, which are represented by joint planes, fissures, shear zones, and foliation, have affected not only the bedded, but also the massive rocks. They may be grouped into two systems, one of which trends nearly north and south, while the other runs northwest and southeast. Both of these systems find expression in the position of the channels and inlets of this coastal belt. (Compare map, Pl. I.)

### SUMMARY.

In the province under discussion Paleozoic terranes ranging from Silurian or older to the Carboniferous have an extensive development. Large masses of green-

[a] Nat. Geog. Mag., Vol. III, 1891-92, p. 167.

tones are intruded in the lowest members of the Paleozoic series. In part of the region, at least, a stratigraphic break is known to occur somewhere in the Devonian. A series of argillites occurs which seems to belong to the Upper Paleozoic horizons, but its stratigraphic position was not determined. The Mesozoic is represented in one part of the region by sedimentary strata, whose basal member is a conglomerate, overlying the Paleozoic rocks unconformably, and in another part by large extrusions of volcanic rocks. There were injections of granite in large masses along the Coast Range axis, probably during Middle or Later Mesozoic times, and in smaller masses elsewhere in the region. The Tertiary is represented by lignite-bearing sediments of Oligocene age, which are only slightly disturbed or indurated. Some volcanic rocks have been extruded in post-Tertiary times. Besides these, dikes of various rock types are present in all the pre-Tertiary beds.

The earliest epoch of intense disturbance was in pre-Devonian time, and was accompanied by large intrusions of basic igneous rocks. The next period of metamorphism was probably in Middle Mesozoic time, when the intrusion of the granite of the Coast Range took place. The alteration of the sediments adjacent to the mass of granular igneous rock is assigned jointly to contact metamorphism and to the mechanical effect of injections. The granite itself shows the effect of deformation, having been locally changed to gneiss and mica-schist. No evidence has been found of any post-Tertiary disturbances commensurate with these ancient revolutions.

## GLACIAL PHENOMENA.

### INTRODUCTION.

Southeastern Alaska is par excellence the region of the world in which to study glaciers, and in the Territory more attention has been given to this branch of geology than to all others. There is a large literature which, directly or indirectly, bears on Alaskan glaciers, but many of the investigations have been rather superficial, and the descriptions have often been scenic rather than technical and accurate. There have been, however, a number of earnest workers who have made detailed studies and investigations. John Muir was the first to call attention to the magnificent scenery of what is now the much-traveled Alaskan tourist route.[a] In 1879 he, in company with the Rev. S. Hall Young, discovered and explored Glacier Bay. Muir subsequently spent several summers in this region, and has written very delightful accounts of it. The Rev. G. Frederick Wright[b] was among the early students of the glaciers of the region, and there have been many others. The more technical studies have been made by Russell,[c] Reid,[d] Gilbert,[e] and others.

[a] The discovery of Glacier Bay: The Century Magazine, June, 1895.

[b] The Ice Age in North America, 1889, Chapter III.

[c] Expedition to Mount St. Elias: Nat. Geog. Mag., Vol. III, 1891-92; Second expedition to Mount St. Elias: Thirteenth Ann. Rept. U. S. Geol. Survey, Pt. II, 1893, pp. 1-91.

[d] Studies of the Muir Glacier: Nat. Geog. Mag., Vol. IV, 1892-93; Glacier Bay and its glaciers: Sixteenth Ann. Rept. U. S. Geol. Survey, Pt. I, 1896, pp. 421-461.

[e] Gilbert's results have not yet been published; they are to appear in a forthcoming volume of the Harriman expedition.

Of the regional glaciation of southeastern Alaska not many details are known, and the lack of topographic data makes it a problem difficult of treatment. It has been discussed by Hayes,[a] Tyrrell,[b] and more especially by Dawson.[c] In the present sketch the writer will not attempt to summarize the literature, but will only present a few generalizations.

### EXISTING GLACIERS.

The existing glaciers of Alaska are particularly limited to the westernmost of the four geographic provinces—the Pacific Mountain system—and the largest development of glacial ice is found on the seaward slope of the St. Elias and Coast ranges.

The average altitude of the St. Elias Range probably exceeds 10,000 feet. On the Pacific side the limit of perpetual snow on this great mountain mass is at an altitude of about 2,000 feet, and it is probably something over 6,500 feet on the inland slope. The interior of the range has never been explored, but is known to include vast snow fields, which Russell viewed from Mount St. Elias and described as "limitless in expanse." A similar description applies to the northern part of the range, which the writer viewed from a point on its inland margin almost due north from Mount St. Elias.

These large névé fields give rise to many glaciers, which discharge on both sides of the range. The glaciers on the inland slope of the range are comparatively insignificant compared with those on the Pacific slope. The largest ice fields of Alaska are to be found along the coast between Cross Sound and the Copper River delta, and they are, in fact, among the largest in the world. The development of glacial ice in this coastal belt is only equaled by that of Greenland. The larger glaciers, which are of the piedmont type, spread out on emerging from the mountain valleys and form those large seas of ice which are such characteristic features of this coast line. The Malaspina Glacier, which is west of Yakutat Bay, presents a front of over 40 miles and is a good example of this type. Besides these piedmont glaciers there are also many of the alpine type, which do not reach the coastal plain. Those of the inland slope of the St. Elias Range are of the alpine type and seldom even reach the floors of the larger valleys.

In the Coast Range glacial ice is developed to a much less extent than in the St. Elias Range. The altitude of the range is not so great and the snow fields are much smaller. The precipitation from the moisture-bearing winds of the Pacific is much more largely in the form of rain than of snow. This is in part owing to climatic variations due to difference in latitude. To the northward the line of perpetual snow rises rapidly, so that near Dixon Entrance it stands between 5,000 and 6,000

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[a] An expedition through the Yukon district: Nat. Geog. Mag., Vol. IV, pp. 117–162.

[b] Glacial phenomena in the Yukon district: Bull. Geol. Soc. Am., Vol. X, pp. 193–198.

[c] On the late physiographical geology of the Rocky Mountain region in Canada, with special reference to the change in elevation and the history of the Glacial period: Trans. Roy. Soc. Canada, Vol. VIII, 1890, sect. 4. Report on the exploration in the Yukon district, N. W. T., and adjacent portions of British Columbia: Geol. Nat. Hist. Survey Canada, new series, Vol. III, Pt. II, 1887–88, pp. 1–277 B.

feet on the seaward side of the Coast Range. The mountainous basin of the Alexander Archipelago, which intervenes between the mainland and the open ocean, probably also has an important effect on the precipitation in the Coast Range.

The glaciers of the Coast Range are of the alpine type, and are almost all on the seaward slope. Lynn Canal receives several glaciers from the Coast Range, but none of them reach tide water. Taku Inlet and Stikine River receive a number of glaciers of considerable size, which have been described by Dawson and others. The coast line between the Stikine and the Taku has many indentations, and large glaciers are tributary to the heads of a number of these. South of the Stikine the glaciers are much smaller. Several are said to drain into the head of Portland Canal. No glaciers exist on the islands of southeastern Alaska. The glaciers of Alaska, as far as known, are all retreating. In the Glacier Bay region this fact has been definitely established by actual measurements made by Professor Reid.

Near the southeastern end of the St. Elias Range is a large névé which is the source of glaciers that radiate in three directions. Of these the glaciers of Glacier Bay are best known, since they are on the well-known tourist route of southeastern Alaska. The Davidson Glacier, emptying into Lynn Canal, has its source in this snow field, as have also a number of smaller glaciers which discharge into the southern tributaries of the Chilkat River.

## FORMER GLACIATION.

The investigations of the past season contributed but very little to the glacial history of the region. It is worth while, however, to record such observations as were made, so that they may be available to those who study the region in future. Evidence of glacial action was found at low altitudes in nearly every part of the Ketchikan mining region, where the more detailed work was done. This evidence was chiefly in the character of the valleys, the distribution of glacial bowlders, and in a few instances glacial striations. At only a few localities was any morainic material observed, and this only in very limited quantities.

The valley floors and the walls of the fiords near sea level usually show evidence of glaciation, but in only a few cases was evidence obtainable in regard to the mountains. Near the western end of Moira Sound, on Prince of Wales Island, evidence of glacial action was found at an altitude of 2,200 feet. Near Niblack Anchorage, on the other hand, the topography suggested at least that the upward limit of glacial action had not been higher than 2,000 feet. In general, however, it can be said that the mountains of the southern part of the Alexander Archipelago have the appearance of having suffered glaciation up to a height of at least 2,000 feet. In the northern part of the area under discussion only a few random observations were made bearing on glaciation. Glacial bowlders are found at Juneau at an altitude of 3,200 feet, and there is also a moraine at the mouth of Gold Creek, on which the town of Juneau is in part located. On the Chilkat River, which is tribu-

tary to Lynn Canal, terraces were observed at an altitude of about 1,000 feet. On the Klehini River, a southerly fork of the Chilkat, similar terraces were noted at an altitude of 1,400 feet. These terraces usually slope toward the axes of the valley. Their material, as far as determined, is sand and gravel, with some silt and occasional bowlders. It seems probable that these terraces were built along the valley walls when the valley was occupied by glacier ice. Evidence of glacial action has been noted by a number of observers along Lynn Canal, Taku Inlet, and the Stikine River.

Among the noteworthy topographic features observed in this region are the rock-cut basins occupied by lakes, which are of not uncommon occurrence, especially in the Ketchikan region. On the east side of Niblack Anchorage, on Prince of Wales Island, is a lake about a mile long and a quarter of a mile broad, which is entirely surrounded by a rock rim. Soundings showed that the bottom of the lake is about 200 feet below sea level, while its surface is now about 100 feet above tide water. Lakes similarly located were seen at other places, but were not sounded. It seems probable, however, that the bottoms of these rock basins frequently reach below sea level. An examination of the Coast Survey charts of the region shows similar depressions in the floors of some of the inlets. There seems to be no other explanation for these basins than that they have been excavated by glacial scouring.

In general it can be stated that all of the valleys and lowlands of southeastern Alaska, including the islands of the Alexander Archipelago, show glaciation. Whether the ice sheet which produced this glaciation overrode the higher mountains of the archipelago or simply occupied the valleys has not been determined, for no definite evidence was found to show that the entire region has been occupied by ice.

Dawson[a] described the glaciation of the northern Cordilleran region at some length. He has shown that the locus of ice accumulation was in northern British Columbia, and that from that center the ice flowed in every direction. Since Dawson made his observations the northern limit of this ice sheet has been more accurately determined by different observers, but, on the whole, there has been but little added to the general knowledge of this glacial epoch.

The following quotation has a bearing on the glaciation of southeastern Alaska:[b]

"A certain proportion of the ice, however, during the maximum phase of this great glacier flowed through passes in the Coast Ranges, and uniting there with ice derived from the western slopes of these ranges, filled the great valley between Vancouver Island and the mainland, impinged upon the shores of the Queen Charlotte Islands, and still farther north reached the ocean across the coast archipelago of the southeastern coast strip of Alaska."

Dawson, therefore, regarded the ice sheet of the coastal belt of southeastern Alaska and British Columbia as being the result of the accumulation of ice and snow on the western slope of the Coast Range. This was distinct from the ice sheet of the interior, but was connected with it by glaciers which occupied the valleys and rivers that break the Coast Range.

[a] Trans. Roy. Soc. Canada, Vol. VIII, 1890, sec. 4.

[b] Dawson, op. cit., p. 27.

Gilbert,[a] who is familiar with this region, is inclined to assign the present coastal topography of southern Alaska to glacial action rather than to depression. He has adduced some evidence which goes to show that since the glaciation there has been no depression in the region. On this point the writer has no evidence to offer. He is, however, very strongly impressed with the fact that ice action has played a very important part in producing the present topographic forms of this part of Alaska.

## THE KETCHIKAN MINING DISTRICT.

### GENERAL DESCRIPTION.

The Ketchikan mining district embraces an area of about 7,200 square miles in southeastern Alaska, and is the southernmost of the several recording districts into which southeastern Alaska has been divided. The district (see map, Pl. II) includes Prince of Wales, Revillagigedo, and many smaller islands, as well as a part of the mainland. It lies between latitudes 54° 40′ and 56° 20′ and longitudes 129° 50′ and 134°. The international boundary marks its southern and eastern limits. The northern boundary of the district follows Sumner Strait, Clarence Strait, Ernest Sound, the Eastern Passage, and Bradfield Canal to its head, from which latter point it runs due east to the international boundary. To the west the district is bounded by the Pacific Ocean, and includes all of the small islands lying adjacent to Prince of Wales Island. A little less than a third of the area of the district is mainland, the rest being included in the islands. Prince of Wales Island is the largest of the islands, and Revillagigedo Island is second in size. The following table shows the approximate areas:

*Approximate areas of principal islands of Ketchikan district.*

| | Square miles. |
|---|---|
| Prince of Wales Island | 2,800 |
| Revillagigedo Island | 1,043 |
| Dall Island | 200 |
| Annette Island | 142 |
| Gravina Island | 100 |
| Kosciusko Island | 100 |
| Duke Island | 60 |
| Bell Island | 19 |
| Hassler Island | 12 |
| Betton Island | 8 |

From a topographic standpoint the Ketchikan district falls naturally into two subdivisions, one lying east and one west of Clarence Strait. The easterly portion embraces Gravina, Annette, Duke, and Revillagigedo islands and the adjacent portions of the mainland. The westerly portion includes Prince of Wales and the smaller adjacent islands.

[a] Gilbert's results have not yet been published, but were briefly summarized in a paper read before the Geological Society of Washington, March 27, 1899.

The easterly part of the district falls within the Coast Range province. This part of the Coast Range consists of a rather rugged mountain mass having no well-defined crest line. The highest peaks reach altitudes of 5,000 to 6,000 feet. Among the higher mountains glaciers are not uncommon, but they are insignificant in size compared with those in the northern part of the range.

Prince of Wales Island is 140 miles in length and has an extreme width of about 40 miles. With its contiguous islands on the west it forms a distinct group, which has a rectangular outline and is separated from the islands and mainland to the east by Clarence Strait. The coast line of Prince of Wales Island is broken by many deep embayments which run far inland. At a number of localities such embayments approach each other from opposite sides of the island and reduce its width to but a few miles. At many places broad valleys with very low divides connect these opposing fiords. A depression of a few hundred feet would flood these divides and resolve Prince of Wales Island into an archipelago. The relief on the island varies from 1,500 to 3,600 feet. The shore line is generally abrupt and the mountains have very steep slopes. The larger valleys have the U-shaped cross sections typical of glaciated regions. In the valley bottoms the streams have incised post-Glacial gorges. Lakes occupying rock-bound basins, which have been scooped out by glacial action, are found throughout the district. Of the drainage but few details are known, as the interior of the island is entirely unmapped. Generally speaking, the streams have east-west courses. The drainage system seems to be very irregular, the watershed being in some places near the eastern, in others near the western coast of the island. The mountains, the highest of which reach altitudes of about 3,500 feet, form no well-defined ranges, but, broadly speaking, have a northwest-southeast linear arrangement. The islands on the west side of Prince of Wales were not visited by the writer and but little information was obtained in regard to them. Their relief is probably less than that of Prince of Wales.

The easterly province, in its relief and general topographic character, can not properly be separated from the Coast Range. Minor ranges extend in a northwest-southeast direction through Gravina, Annette, and Duke Islands. The mountains of Revillagigedo Island and the mainland in general parallel the coast, and also the dominant structural lines. They are divided into many minor groups, within which there is no systematic arrangement or correspondence to rock structure. On these islands and on the Cleveland Peninsula to the north the drainage follows northerly and southerly courses, parallel to the trend of the mountains. On the mainland to the east the principal water courses lie transverse to the axes of the ranges as a whole. The chief rivers empty into the heads of the fiords, whose directions are the continuation of their approximately northeast-southwest courses. The Unuk River is the largest of these transverse streams. Only a part of its course has been mapped, but its source must lie near the eastern limit of the Coast Range or within the Plateau region beyond.

In its upper course it is said to occupy a narrow, rock-floored valley, but about 20 miles from the coast it broadens out, and is floored with gravel to its mouth at the head of Burroughs Bay. Twenty miles south of Burroughs Bay the Chickamin River enters Behm Canal from the east. It has a broad delta at its mouth, and for some miles up a wide, gravel-floored valley. Its source lies within the Coast Range among high mountains which give rise to a number of glaciers. The other mainland streams of the Ketchikan district are comparatively small and rise within the Coast Range. The largest are those which are tributary to the head of Portland Canal.

## HISTORY.

During the Russian occupation of Alaska, then known as Russian America, little or no attempt was made to investigate its mineral resources. A little coal mining was done on Cook Inlet, but, while it seems certain that the Russians had knowledge at least of the existence of the deposits of chalcopyrite ore, which form extensive outcrops along the beach on the north shore of Kasaan Bay, the development of this and other metalliferous deposits was consistently avoided.

Gold is said to have been discovered on the Stikine River in 1861, but it was not until after the transfer of Alaska to the United States that any attempts were made at placer mining. In 1865 the Russians sent an expedition to the Stikine River for the purpose of establishing the boundary between the Russian and English possessions. Prof. W. P. Blake accompanied this expedition as a volunteer, and made notes on the geology of the region, which were subsequently published as a Congressional document,[a] and which constitute the first authoritative information in regard to the mineral resources of southeastern Alaska. Blake noted the presence of placer gold on the Stikine River. The workable deposits were chiefly on the Canadian side of the international boundary.

During the early seventies many miners went to the newly discovered Cassiar gold district of British Columbia, and at that time a little prospecting was done in southeastern Alaska. The main route of travel to the Cassiar diggings was via Wrangell and the Stikine River. About the same time gold was reported from the Unuk River, but there was no systematic attempt to develop the field.

It is said that a party of prospectors, attracted by the reports of the Russian traders concerning the occurrence of copper on Kasaan Bay, visited Prince of Wales Island during the years 1870 to 1874 and discovered valuable deposits of copper.

The comparative isolation of the district, and the fact that such enormous quantities of native copper had been found in the Lake Superior region, are probably the reasons that these sulphide deposits of Prince of Wales Island attracted but little attention. Moreover, the gold deposits of the northern part of southeastern Alaska attracted most of the prospectors. Gold-bearing quartz veins had been discovered

[a] House Ex. Doc. No. 177, Pt. 2, Fortieth Congress, second session.

near Sitka in 1873,[a] and systematic development was begun in 1877. This was followed in 1880 by the discovery of the gold placers and gold-bearing quartz veins near Juneau.

During the succeeding years, while the mines near Juneau were being opened up, the Ketchikan district was entirely neglected. It was reported that valuable ore deposits existed on Prince of Wales Island, but prospectors seem to have regarded the rumors as not sufficiently definite to warrant any attempt at verification. In his Tenth Census report Petrof[b] mentions a mine which had been opened on Prince of Wales Island but which had subsequently closed down. Though he does not give the location of the mine, it is probable that he refers to abortive attempts at the development of the copper deposits on the north side of Kasaan Bay, near the present location of the Copper Queen. Miner W. Bruce, in his report to the Eleventh Census, states that "surface indications" on Prince of Wales Island indicate that it contains important mineral resources. The following is quoted from his statement:[c]

"The indications on the surface are that Prince of Wales Island contains much mineral. Gold, both free milling and in sulphurets, silver, galena, copper, and iron have been found in many places, but as yet no extensive efforts have been made to demonstrate whether any of the ores mentioned exist in paying quantities. If minerals exist in other portions of the district, the very limited prospecting done has failed to show it. Annette Island may be an exception, and also Dall Island. Some of the finest specimens of gold-bearing ore I have seen in my journey are said to have been taken from Dall Island."

Whatever may have been Mr. Bruce's authority for making the above statement, it is certain that at the time of his visit but little prospecting had been done on Prince of Wales Island.

It was the men who were engaged in salmon fishing who were next to interest themselves in the presence of ore bodies in the Ketchikan region. These men, whose vocation of hunting and fishing led them to explore the coast line of the region, had their attention called to the numerous quartz veins, and the more intelligent and energetic among them were led to do a little prospecting. They met with favorable results and were encouraged to continue. Prominent among them in 1892 was James Bowden, who discovered what he believed to be workable gold deposits on the eastern side of Annette Island. In 1897 discoveries were made on Gravina Island and near Boca de Quadra.[d] In the succeeding year a number of important locations were made, notably the Gold Standard property on Cleveland Peninsula, and some of the copper prospects at the northern end of Gravina Island.

During the Klondike excitement of 1897–98, Wrangell became an important transshipment point, as, during the Cassiar rush many years before, the Stikine

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a Population and Resources of Alaska, Eleventh Census of the United States, 1890, pp. 229, 230.
b Population, Industries, and Resources of Alaska, by Ivan Petrof, Tenth Census of the United States, 1884, p. 77.
c Population and Resources of Alaska, Eleventh Census of the United States, 1890, p. 39.
d Report of the Governor of the District of Alaska, 1897, p. 31.

River was used as one of the routes into the interior. Some of these prospectors found their way into the Ketchikan district. A party of these disappointed argonauts which landed in Johnson Inlet, on Prince of Wales Island, learned of the discovery of gold in the vicinity through Paul Johnson, an Indian boy. The members of this party made many locations, and began some preliminary developments.

During this period exploitation was going on actively at Helm Bay and on the Sea Level property near the head of Thorne Arm. Also some preliminary work was being done at several localities on Tongass Narrows, and at Seal Bay and Dall Head, both at the southern end of Gravina Island. In 1898 prospecting was begun at Copper Mountain, on Hetta Inlet, Mount Andrew and Copper Queen, on Kasaan Bay, and in the following year discoveries were made at Hollis, Niblack Anchorage, and on Skowl Arm. The last two years have seen great activity in the Ketchikan district, and probably several hundred claims have been staked. At a number of localities systematic mining has been undertaken. More detailed descriptions will be found in the succeeding section of this report.

The mineral products of the district which have thus far been marketed are gold, silver, and copper. In spite of the fact that hardly a single mine can be said to have yet reached a shipping basis, the district to the end of 1901 produced probably over $100,000 in gold and upward of $20,000 worth of copper.

The town of Ketchikan, which is the general distributing point for the district, is located on the west side of Revillagigedo Island and on the east side of Tongass Narrows. With a population of 600 to 700, and ample stores and hotels, it makes a good outfitting point for those who wish to examine the district. It can be reached by steamer from Puget Sound ports in two or three days. As Ketchikan is the port of entry for southeastern Alaska, all the steamers, both from Puget Sound and from Canadian ports, have to make landing. It has therefore excellent steamboat connections and ample wharf facilities. A small but comfortable steamer makes regular trips from Ketchikan to the various mining camps on the east side of Prince of Wales Island. There are also a number of small launches and sloops at Ketchikan which can be chartered for cruising among the islands.

The prices of provisions and supplies are not much in advance of those of Seattle. In 1901 freight rates were quoted to the writer as follows: From Seattle to Ketchikan, $8 a ton; from Ketchikan to points on Prince of Wales Island, $3 per ton. Coal retails at Ketchikan for $11 a ton. Lumber varies in price, but for small lots sells for about $15 or $16 per thousand. Wages in 1901 were $2.50 to $3 per day and board, but experienced miners were very difficult to find.

Up to the time when the mining excitement began salmon canning was the chief industry of the region. Canneries are located at Ketchikan, Loring, Metlakatla, and at a number of points on the west side of Prince of Wales Island. There are also many salteries within the district, where the salmon are salted instead of canned. The canneries and salteries are usually in operation from about the middle of June until the 1st of October.

## GEOLOGY.

### INTRODUCTION.

The greater part of the two months which were devoted to the study of the Ketchikan district was given to an examination of the ore deposits, and the mapping of the geology was necessarily made incidental to the economic work. For this reason, and because there are no topographic maps of the region, the distribution of the formations can be represented only in the most general way. The general geologic observations which have been made are in many cases not sufficient to warrant more than tentative conclusions, but it is believed that the descriptions and the general succession of formations as here presented will not be materially modified when the region is studied in detail, though the formations will undoubtedly be more minutely subdivided and many structural features will be found which were entirely overlooked in the work of last season.

The oldest rocks of the district are crystalline limestones and phyllites, which occupy a large area on Prince of Wales Island and have been called the Wales series. They are believed to be of Silurian or pre-Silurian age.

Succeeding these is a series of bluish limestones, calcareous schists, and black slates, which was found along the western part of Gravina Island. It has been named the Vallenar series, from its typical exposures on the bay of the same name. Fossil evidence goes to show that this series is, at part at least, of Middle Devonian age.

The name Ketchikan series has been applied to a succession of argillites with some limestones and arenaceous beds which are found along the eastern margin of Gravina Island and along the western margin of Revillagigedo Island. These rocks are believed to be in part Paleozoic and in part Mesozoic.

On the southern end of Gravina Island massive conglomerates were found unconformably overlying the Vallenar rocks. These have been termed the Gravina series, and are provisionally assigned to the Mesozoic. At Coal Bay, an arm of Kasaan Bay, some lignite-bearing beds occur, which are believed to be Tertiary.

Igneous rocks have a wide distribution in the region, granite being among the most abundant. The eastern part of the district is occupied by a broad, batholitic belt of granite, which is the principal constituent formation of the adjacent portion of the Coast Range. This is found cutting the Ketchikan series. At various other localities granite stocks were found. Pegmatite is not uncommon in dikes, and syenite was found at one locality. Diorites are widely distributed as stocks, dikes, and sills. Gabbros and amphiboles also occur among the intrusives. Greenstone-schists are widely distributed and are found associated with all the sedimentary beds except the Gravina series. They are made up chiefly of chlorite, with some actinolite, epidote, and other schists. Diabases are very common, and belong to the latest intrusions in the region. Of the effusive rocks, which are also well repre-

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sented in the district, the most abundant is the porphyritic rock which has been termed the Kasaan greenstone. Its general character is that of an andesite, but it shows great local variations, and probably includes some intrusive rocks. Rhyolites, trachytes, and basalts were also noted at a few localities.

## BED-ROCK GEOLOGY.

### SEDIMENTARIES.

*Wales series.*—A belt of argillites and white limestones extends in a northwest-southeast direction through Prince of Wales Island, and these, with the possible exception of some gneisses found associated with the granite, are the oldest rocks of the district. These argillites and limestones, together with closely associated greenstones, have been provisionally grouped as one formation under the name Wales series, although eventually the series will unquestionably be further subdivided. This belt is interrupted in many places by areas of younger effusive rocks, which will be referred to hereafter.

The series as a whole can be divided into two parts, one of which is prevailingly argillaceous, while the other is essentially calcareous. Both the argillites and limestones are intensely folded, and they are frequently much metamorphosed. The reconnaissance did not allow the definite establishment of the age relations of the two portions of the series, but the greater part of the evidence points to the conclusion that the argillites are older than the limestones. This idea of the relative position of the two portions of the Wales series is supported by the known succession of argillites and limestones probably of the same age at Glacier Bay.

In the Ketchikan district the argillaceous part of the Wales series is well developed west of Twelvemile Arm, in the vicinity of Hollis. At that locality the rocks are typical clay slates and phyllites, often carrying graphite and including some interbedded arenaceous strata. Intrusives of a basic character are not uncommon. To the east of the argillites is a belt of white crystalline limestone apparently overlying the argillites. From notes obtained from prospectors it seems probable that these argillites extend to the northwest and form the country rock of the gold-bearing region southwest of Karta Bay. Similar argillites were found at the western end of Moira Sound, where they also appear to underlie the crystalline limestones which outcrop to the east. Schrader reports that argillaceous and arenaceous sediments outcrop on Hunter Bay, near the southern end of Prince of Wales Island, which are probably of the same series.

The limestones of the Wales series are much more extensively developed in the Ketchikan district than the argillites. They are traceable as a broken belt from Moira Sound northwestward to the western part of Kasaan Bay and westward to Hetta Inlet, which was the limit of the reconnaissance. Marble is reported at the northern end of Prince of Wales Island. The limestone is typically white or bluish white, crystalline, and often dolomitic. It is usually much

jointed and sometimes schistose. Basic intrusives are everywhere closely associated with the limestone, occurring as narrow sills and dikes and also as broad belts within the limestone area. These greenstones are always schistose and sometimes finely foliated. They are apparently of an intrusive character, though it is possible that some of them are tuffaceous. Narrow belts of graphitic slates and phyllites occur within the limestone area, locally producing a resemblance to the underlying argillites, which made it impossible to differentiate the upper and lower members of the Wales series.

No measurement of the thickness of this series was obtained. It seems probable, however, that the limestone alone is several thousand feet thick.

The age of the Wales series was not determined. It will be shown below that the succeeding rocks, which overlie them unconformably, are of Middle Devonian age. The northern extension of what is believed to be the same series has been shown to carry Upper Silurian fossils, and it will therefore be provisionally assigned to the Silurian.

The rocks of the Wales series carry important ore bodies. The phyllites are fractured, and in several localities are cut by true fissure veins containing ores which sometimes carry good values in silver and gold. Similar veins are found intersecting the crystalline limestones. As will be shown below, some of these seem to be replacement. Another form of ore-bearing veins, which carry both copper and gold, occurs at the contact of crystalline limestone and intrusive igneous rocks. Mineralized zones containing copper and gold are found in some of the schistose intrusives which cut the Wales series. Workable beds of marble are reported to have been found in this series.

*Vallenar series.*—The next succeeding horizon is the Vallenar series, so named from its type exposures on Vallenar Bay, at the northern end of Gravina Island. The series is composed essentially of limestones and calcareous schists with some black slates.

The distribution and metamorphism of the Vallenar series are somewhat puzzling. At Long Island in Kasaan Bay blue limestones carrying Devonian fossils are well exposed. These are only gently folded and appear to unconformably overlie a quartz-schist which contains much feldspar. At Vallenar Bay, on the other hand, is exposed a similar fossiliferous limestone which has been much crumpled and considerably altered. It will be shown that this increase in metamorphism to the east is probably due to the action of the intrusive Coast Range granite. Such local variation in the amount of metamorphism makes it probable that the Vallenar series will eventually be identified in other localities, among certain of the metamorphic limestones which have here been assigned to the Wales or Ketchikan series.

The Vallenar series has been mapped as a broad belt on the western side of Gravina Island. It was positively identified, however, only at Vallenar Bay. At

the southern end of the island were found calcareous schists and black slates which are provisionially assigned to this horizon. The correlation of the beds at the two ends of the island rests upon a very slender foundation.

The Vallenar rock, like the underlying beds, contains intrusions of greenstones of various character. These are usually schistose and often highly contorted. At Dall Head, in Seal Bay, occurs a system of pegmatite dikes cutting both the Vallenar series and the associated greenstones. These are of interest because of the close association of the ore bodies with them.

On Gravina Island the eastern limit of the Vallenar rocks is marked by what is believed to be a fault, and no determination of their thickness could be made. At Long Island the blue limestone which there forms the basal member of the series is probably 200 feet thick.

The discovery of fossils at Long Island definitely determines the age of a part, at least, of the Vallenar series. These fossils were referred to Mr. Schuchert, who reports as follows:

"The specimens from Long Island are *Favosites* near *F. epidermatus* in abundance; *Callopora?*; *Pugnax* sp. undet., a small species; *Gypidula* sp. undet., a strongly plicated small species; *Atrypa reticularis* Linné; *Parazyga* apparently near *P. hirsuta*; *Campophyllum* sp. undet., a large species with a very deep cup; and *Acervularia* with large coralites. The specimens from Vallenar Bay include a rhomboporoid bryozoan unknown in rocks older than Devonian. The age may be the same as the coral-bearing strata of Long Island.

"The age of the fossils from the above-mentioned localities is Middle Devonian. While each lot has a different association of species, all are of Middle Devonian age, but may represent different horizons.

"Similar Alaskan coral faunas of Middle Devonian age are known on the Upper Kuskokwim at latitude 63° 10′, longitude 154° 56′, and near Cape Lisburne, on the Arctic coast.

"From Kuiu Island, in southern Alaska, a few fossils of Middle Devonian age are known, but the fauna is quite different in that it contains no corals. A different horizon, possibly a lower one, may be indicated."

As has been shown, Schuchert regards these beds as in general synchronous with the horizon from which a coral was secured in the débris of Dirt Glacier of Glacier Bay.

A broad depression, which connects Vallenar Bay on the north with Bostwick Inlet on the south, divides Gravina Island into two distinct parts. The western part is believed to be occupied chiefly by the rocks of the Vallenar series; to the east are slates and greenstones which belong to the Ketchikan series. While there is no positive evidence, the topographic features suggest that there has been faulting along this depression.

At the southern end of Gravina Island important copper deposits have been found in rocks which were correlated with the Vallenar series. These occur associated with the pegmatite dikes which have been referred to.

*Ketchikan series.*—The rocks of this series are argillaceous and arenaceous schists, forming a belt which lies between the Vallenar rocks and the granite of the Coast Range. They were found in the vicinity of Ketchikan, on both sides of the Tongass Narrows, on the western part of Revillagigedo Island, on the Cleveland Peninsula, along George Inlet, and on the eastern side of Behm Canal as far as Traitors Cove. They are also found in Thorne Arm, George Inlet, and in the lower part of Carroll Inlet. They are for the most part finely foliated slates and phyllites, usually carrying considerable graphitic or carbonaceous matter. East of Ketchikan they include some arenaceous beds which are more or less flaggy. While for the most part argillaceous, they also include some limestone areas, which seem to be an integral part of the series. As far as could be determined, the limestones belong to the upper part of the series, and the lower part is practically devoid of calcareous matter.

The limestones which were observed in this series are limited to two or three belts in the vicinity of George Inlet and Throne Arm. These limestones are white or bluish, usually quite crystalline, much jointed, and sometimes foliated. It is possible that the structure in the vicinity of these limestone beds has been misinterpreted, and that they, as a matter of fact, belong to an older series which has been infolded with the argillites.

The beds of this series strike northwesterly and southeasterly with varying dips. Usually they are closely folded. Going eastward across the strike, one finds the argillites to be more metamorphosed and the folding more intense as the granite is approached. Near the contact the rocks are altered to phyllites and sometimes to mica schists. This fact suggests the possibility that the mica-schists which occur within the Coast Range granite belt may belong to the Ketchikan series.

The eastern limit of the Ketchikan series is formed by the Coast Range granite mass. These granites are intrusive, and near the contact there is usually an irregular succession of slate and granite belts.

Neither the thickness nor the age of the Ketchikan rocks could be determined, but near Coon Island, on George Inlet, the limestones of the series were found to contain many crinoid stems, which suggests that the limestone at least belongs to the Upper Paleozoic. In the sketch of the geology of southeastern Alaska a belt of argillites is described (p. 24) which includes the Ketchikan series and which lies adjacent to the granite on the west. Evidence is there presented which tends to show that these rocks are in part Mesozoic; an attempt to correlate them with the described formations of adjacent portions of British Columbia suggests that the limestones of the Ketchikan series are Carboniferous, and that the argillites may be Triassic, and therefore younger than the limestones. However, the structural relations of the limestone beds, as far as determined, lead to the conclusion that the argillites are the older. At present, therefore, it is impossible to state definitely the age of the Ketchikan series, or its relations to the Wales and Vallenar series.

Intrusives are very common throughout the area occupied by the Ketchikan

series. Besides the main mass in the Coast Range, smaller stocks of granite are occasionally found, and intrusive greenstone is of very common occurrence. A belt of fine-grained greenstone-schist, which the microscope shows to have been derived from a diabase, is exposed on both sides of Tongass Narrows, and is again found on Betton Island and Cleveland Peninsula. Granular rocks resembling diorite also occur, and these were observed to cut the diabase.

The Ketchikan series is important from an economic standpoint. The phyllites are jointed and fissured, and the fissures are sometimes filled with gold-bearing veins. Within the greenstones of this series there are mineralized zones which afford gold ores. Notable examples of the latter are the ore deposits of Cleveland Peninsula.

*Gravina series.*—This is a series of massive conglomerates overlain by black shales or slates and closely infolded with the rocks of the Vallenar series. It was observed at Dall Head and elsewhere on the southern side of Gravina Island, and although it has not been identified with certainty elsewhere in the region, more detailed investigation will doubtless reveal its presence. At Niblack Anchorage, on Prince of Wales Island, at an open cut on the Lookout claim, a small outcropping of heavy conglomerate was observed, which may be of the same age as that on Gravina Island. Schrader reports a similar conglomerate on Hunter Bay, at the southern point of Prince of Wales Island. Notes obtained from prospectors indicate a similar occurrence at Union Bay, on the northern side of Cleveland Peninsula. The basal bed of the series is a massive conglomerate composed of usually rounded pebbles representing the various types of rock occurring in the adjacent formations. Above the conglomerate there are black shales and slates. Both the conglomerate and the shales have been intensely squeezed, and the former is much jointed and fissured. The evidence points toward the conclusion that previous to the deposition of the Gravina series the region over which it was laid down had existed as a land area, subject to subaerial erosion. The coarse conglomerates at the base of the series mark the advance of the sea over this ancient land. In the general discussion of the geology of southeastern Alaska it has been shown that this series is probably the equivalent of the Mesozoic beds on the Stikine River, the Taku River, and the Upper Lewes River, and of the Kennicott formation of the Copper River district. On the Queen Charlotte Islands Dawson has shown that a comparable stratigraphic break occurs near the base of the Cretaceous. It is thus probable that the placing of the Gravina series in the Cretaceous is correct.

*Tertiary beds.*—It has already been shown that Tertiary beds, chiefly of Kenai age, have a wide distribution in southeastern Alaska, though they aggregate no great thickness. Within the Ketchikan district the Tertiary has been found at only one locality, and there its age could not be definitely determined. At Coal Bay, a southern arm of Kasaan Bay, some lignite-bearing beds were found, and are believed on general grounds to be of Kenai age. These beds consist of soft feldspathic sandstone with some shale, which is almost horizontal. The lignite seams thus far

the region, and its unaltered occurrences belong to the latest intrusion. The typical diabase usually occurs in small dikes and carries olivine. The olivine-diabase usually shows its characteristic mineral in the hand specimen. The olivine is contained in a dark-green crystalline groundmass. In thin section the olivine occurs as well-developed phenocrysts, with a groundmass having an ophitic structure and consisting of plagioclase, brown pyroxene, and small irregular olivine grains, together with leucoxene, magnetite, etc. These olivine dikes seem to have been the feeders for the basalt flows which are not uncommon in the region. Another type of diabase is similar in character except that it does not carry olivine.

The diabases which are described in this section are all massive, and have been intruded since the latest deformation of the region. Among the greenstone-schists, however, there are many rocks which are apparently altered diabases, and which will be referred to later.

*Gabbroic rocks.*—Rocks of this type are very uncommon in the district. On Moira Sound was found a small exposure of coarsely crystalline basic rock which is much weathered but is probably an altered gabbro. In thin section large semi-idiomorphically developed plagioclase individuals were observed, with a cement of amphibole, chlorite, and epidote, probably derived from the original dark silicates. A similar type of rock was observed on the West Arm of Cholmondeley Sound. This contained pyroxene as a dark silicate.

On Copper Mountain, in Hetta Inlet, a finer-grained rock was found in contact with a crystalline limestone. This rock was made up of plagioclase and pyroxene and various other minerals. It is provisionally classed with the gabbros.

*Amphibolite.*—At Copper Mountain and at several other localities dikes of a pale-green aphanitic rock were observed, which in thin section was found to be made up almost entirely of a granular aggregate of a highly refractory mineral, probably an amphibole.

*Greenstone-schists.*—The most common igneous rocks of the region are schists, made up of various minerals but having the common characteristic of being igneous and green in color. They are here grouped together because of lack of detailed work to differentiate them. They are usually highly schistose, though sometimes more or less massive. One type is directly traceable to alterations of fine-grained diabases; others, again, are altered diorites. They occur in the Wales, Vallenar, and Ketchikan series. They probably belong to different periods of intrusion, but these can not be differentiated without further studies. A very common type is a quartz-chlorite-schist carrying some feldspar and often some amphibole. Some few also carry considerable pyroxene. Where amphibole predominates they can be classed as amphibole-schists or as actinolite-schists. The more basic types are epidote- and zoisite-schists. With these are also classed some talc-schists, which are evidently alterations of still more basic rocks, and which were found at only a few localities. While most of these schists are believed to be alterations of intrusive rocks, it is possible that some are of extrusive origin.

Another type of schistose rock was found at Niblack Anchorage. This is essentially a quartz-feldspar-schist, often containing considerable chlorite and sericite. In its least altered form it consists of a crystalline aggregate of orthoclase and quartz, often with chlorite and sericite, but it has usually been sheared, altered, and reduced to a quartz-sericite-schist. These quartz-sericite-schists consist essentially of fine mosaics of quartz and sericite, with occasionally some feldspar. They are most likely an altered rhyolite. The schist forms a belt probably half a mile or three-fourths of a mile in width, which is traceable for at least a mile in a northwesterly-southeasterly direction. It is intruded in the greenstone-schists, which in turn are intruded in the Wales series. A similar schist was found on the South Arm of Cholmondeley. It is of special interest because it contains important bodies of copper and gold. Most of the rhyolitic rocks of the region belong to the more recent intrusions, and it seems probable that their extrusion took place in Mesozoic or later times. The rhyolitic schist at Niblack Anchorage is a much older intrusion, and has no connection with the more massive rhyolites.

*Kasaan greenstone.*—Of the igneous rocks in the Ketchikan district the Kasaan greenstone has the most extensive development. It occurs in a variety of types, but as a rule it is a pale- or dark-green massive rock, more or less jointed, usually with well-developed phenocrysts of plagioclase feldspar. The groundmass has considerable variation in its lithologic constituents, but it is usually microcrystalline and made up essentially of plagioclase feldspar and hornblende or augite. It frequently contains orthoclase and considerable quartz, and thus approaches a rhyolitic type. In other cases augite is not an uncommon constitutent of the groundmass. Magnetite is a common accessory. Some phases of this rock are apparently diorites, both in structure and in composition. They differ, however, from the other diorites of the region in being much fresher and in being always porphyritic. As the Kasaan greenstone is believed to be largely effusive, these dioritic phases probably represent the central portions of large flows which have been exposed by erosion. Intrusive rocks are, however, probably included in this greenstone complex.

The Kasaan greenstone is typically quite massive, with, however, marked systems of jointing. In some localities well-developed shear zones are found in it. These seem to be of rather local character and to follow lines of faulting.

On the accompanying map, Pl. II, the approximate distribution of the Kasaan greenstone is shown. More detailed work will probably show many errors in this mapping, as it is often impossible in the field to distinguish the Kasaan greenstone from the older greenstones associated with the Wales series.

The belt of this rock which occupies the western part of Cleveland Peninsula is of the dioritic phase. In the peninsula lying between Clarence Strait and Kasaan Bay, and also on the eastern branch of Skowl Arm, the greenstone contains a number of shear zones.

Within the greenstone are found some narrow belts of limestone, which are

too small to be represented on the geologic map. These limestones are usually crystalline, but are not as much sheared as those of the Wales series. Their origin and age is an unsolved problem, but they probably represent the land floor on which the greenstone was poured out, and can be provisionally correlated with the Devonian of the Vallenar series.

The Kasaan greenstone was extruded after the deformation of the Wales and Ketchikan series. It seems probable that it is of later origin than the Coast Range granite, for it shows evidence of having suffered during the crustal disturbances which accompanied this intrusion. The greenstone can therefore be assigned to a date later than the Triassic. It has been shown elsewhere that there was volcanic activity in the Queen Charlotte Islands during Lower Cretaceous time, and the Kasaan greenstone is probably a manifestation of the same period of eruption.

This formation possesses considerable economic interest from the fact that it contains copper ores, and possibly nickel ores as well. The peculiar copper deposits of Kasaan Peninsula are associated with this rock, as are also the copper and nickel deposits of the Skowl Arm region.

*Rhyolites.*—Rhyolites are not uncommon in the Ketchikan region. They were found as dikes and small flows in all parts of the district. At most localities they were so much altered that it was difficult to determine their original character. On the east side of Twelvemile Arm, near the Lavinia claim, some exposures of rhyolite were found which showed flow structure and other evidence of their extrusive character. In this rock phenocrysts of quartz and orthoclase are scattered through a finely laminated groundmass of cryptocrystalline character. The groundmass consists of kaolin and other secondary minerals, and is probably a devitrified glass. These rhyolites probably belong to the same general period of extrusion as the Kasaan greenstone. Mention has already been made of a quartz-feldspar-schist which is believed to be an altered rhyolite.

*Trachytes.*—Trachytic rocks were found at only two localities, and in both cases the exposures were so much weathered that the identification was doubtful. At the head of the South Arm of Moira Sound are exposures of a bluish, fine-grained, crystalline rock which in thin section showed small phenocrysts of orthoclase in a groundmass made up chiefly of orthoclase with some calcite and sericite. A similar rock was found in the Southwest Arm of Moira Sound.

*Basalts.*—Basalts are not common in the Ketchikan district, though they have been described from many localities in adjacent areas. Those that were found differ very little in character from the diabases which have already been described. They occur as small flows, and all those that have been studied carried olivine.

### SUMMARY OF GEOLOGIC HISTORY.

The strata of the Ketchikan district comprise both sedimentary and igneous rocks, representing sedimentary deposits and volcanic activity since early Paleozoic

time. At various periods there have been important crustal adjustments within the region, some of which have been wide reaching, while others have been quite local in their effects. The final result of these disturbances and the subsequent erosion of the region has been to leave the formations, as they outcrop at the surface, disposed in belts having a general northwest-southeast strike. Along any one of these belts the rocks are characterized by lithologic uniformity, while in a direction at right angles to this they are extremely variable.

The earliest records of sedimentation in the Ketchikan district are contained in the Wales series, which forms the country rock of the greater part of Prince of Wales Island. It is possible that certain of the gneisses and mica-schists found associated with the granite of the Coast Range represent a still older series, though these are in part known to be derived from the surrounding sediments or from the granite itself.

The lower part of the Wales series is predominantly argillaceous and the upper part calcareous. The calcareous beds are believed to be of Silurian age, and the underlying argillaceous beds are presumably Lower Paleozoic. The fact that Cambrian rocks have an extensive development in a province not far distant suggests that these Lower Paleozoic sediments may include Cambrian strata. After their deposition these beds were indurated and then intensely plicated by crustal movements. During this period of disturbance, which was probably in early Devonian times, extensive injections of igneous rocks of a basic character took place. These igneous rocks were in part subjected to the same deformation as the sediments with which they are associated.

The close of this cycle left a part of the land mass above water and subject to stream erosion. After partial degradation submergence followed, and the deposition of the Middle Devonian limestones and carbonaceous shales took place. These two latter are grouped together under the name Vallenar series.

The general facts of the geologic history of the region are fairly clear up to and including the deposition of the Vallenar series. The records of the succeeding epochs are obscure, and the stratigraphic succession has not been determined.

East of the Vallenar series is a belt of more or less altered argillites and beds of crystalline limestone, which constitute the Ketchikan series. What evidence there is points toward the conclusion that this series contains strata of both Upper Paleozoic and Mesozoic (Triassic?) age. The eastern boundary of the Ketchikan series is formed by the granite rocks of the Coast Range. These granitic rocks occupy a large area in the eastern part of the district. They include both massive and gneissoid, and even schistose, phases. The former are plainly intrusive in the argillites to the west, while the gneisses and schists are believed to be sheared portions of the massive granite. The intrusion of this great batholith would cause not only extensive contact metamorphism but also considerable mechanical deformation. The metamorphism caused by this intrusion affected the

entire Ketchikan series, and probably caused more or less disturbance among the rocks lying still farther to the west.

Subsequent to, or possibly during, the granitic invasion large masses of effusive rock were poured out in the western part of the district. The most important effusive type has been termed the Kasaan greenstone, which is of an andesitic type. These volcanic rocks are provisionally assigned to the Mesozoic.

During Mesozoic times (probably early Cretaceous) the Gravina series, made up of fragmentary material, chiefly conglomerate and slate, was deposited unconformably upon the Ketchikan series. Its position in the stratigraphic column is inferred mainly from its analogy to the beds of Cretaceous age found on the Queen Charlotte Islands. All of these Mesozoic rocks, both sedimentary and igneous, have suffered more or less deformation. Indeed, the granite, Kasaan greenstones, and Gravina series were all affected by the crustal movements which followed the depositions of Mesozoic times. The disturbance seems to have been most intense within the Coast Range granitic area, and to have decreased to the westward. It was probably during this period of deformation that the later dike rocks were injected and many of the ore bodies formed. Record of deposition during Tertiary time was found at only one locality, though beds of this period are not uncommon in other parts of southeastern Alaska. These beds have been only slightly deformed.

The crustal movements in later Tertiary times were principally continental in their character, but the knowledge of the region is too limited to warrant definite statements concerning them. During Tertiary times much of the land mass was reduced to a peneplain, out of which during subsequent elevation the present land forms were carved. The position of the major drainage channels was dependent on structural features. Subsequent to the development of a topography very similar to that we see to-day, the ice invasion took place and scoured out and deepened the preexisting valleys and fiords. This was probably followed by a slight depression.

The salient facts in the geologic history of the region are as follows: The Wales series was first deposited. The district was then uplifted, folded, and subjected to erosion and again submerged. Then followed the deposition of the Vallenar, Ketchikan, and Gravina series. The district was then again uplifted and folded and the Coast Range granite was intruded. The land was then again subjected to erosion and was then probably slightly depressed.

## ECONOMIC GEOLOGY.

### GENERAL RELATIONS.

In the character and mode of occurrence of its economic products the Ketchikan district offers greater variety than any other mining region which has thus far been exploited in Alaska. The metalliferous deposits of the district show the presence in commercial quantities of gold, silver, copper, zinc, lead, and perhaps nickel. Other possible mineral values lie in the marble, which has received a limited development, and in the granite and the limestone.

Gold placers have been found in the district, but they are not extensive and do not form an important source of gold. Gold occurs in veins and mineralized zones, both free and in pyrite, and to a limited extent in tellurides. Silver is closely associated with gold deposits in galena, and in limited quantities in tetrahedite. The copper ores of the region, in the order of their importance, are chalcopyrite, malachite, bornite, chalcocite, and cuprite. Of these the first four form the important ore bodies thus far discovered. The copper deposits show a great variety of occurrences, both in veins and in mineralized zones. The zinc occurs as sphalerite (zinc blende) and in association with both copper and silver-lead ores. Nickel has been reported to occur in some of the pyrrhotite, which is associated with chalcopyrite ores.

On the map, Pl. II, the principal mining localities of the Ketchikan district are shown. For convenience of description these localities are arranged in groups, to which local names have been applied, and these are printed in red on the map. The following are the locality names, arranged in the order in which they will be described: Cleveland Peninsula, Tongass Narrows, George Inlet, Thorne Arm, Seal Bay, Dall Head, Vallenar Bay, Niblack Anchorage, North Arm of Moira Sound, Dolomi, Kitkun Bay, South and West arms of Cholmondeley Sound, Twelvemile Arm, Hetta Inlet, Skowl Arm, Kasaan Peninsula, and Tolstoi Bay.

The deposits of Cleveland Peninsula occur in gold- and silver-bearing fissure veins and mineralized zones. The gold ores are both free milling and refractory. They occur in greenstone-schists, which are altered intrusives in the Ketchikan series. The Tongass Narrows deposits are similar in character and represent a southern extension of the same belt. As far as present developments show, they do not compare in richness with those of the Cleveland Peninsula. The Thorne Arm ore bodies are true fissure veins, usually closely associated with porphyry dikes which cut greenstone-schists belonging to the Ketchikan series. The ore is chiefly gold, which occurs both free and combined. The veins, which follow the dikes, are characterized by their persistence, and seem to carry rather uniform though not high values. In George Inlet one class of veins carries chiefly pyrite bearing gold and free gold, and another galena and zinc blende. The veins apparently follow fissures, and the country rock is an argillite, belonging to the Ketchikan series. At Seal Bay and Dall Head the ores are chalcopyrite, and occur

along zones of brecciation near the contact of greenstone-schists and pegmatites. They carry some gold values. The Niblack Anchorage deposits carry chiefly copper, with some gold. They consist of immense mineralized zones, carrying persistent though low values, in a feldspathic schist, which is probably an intrusion. This feldspathic schist cuts greenstones, which in turn are intrusive in the Wales series.

On the west side of North Arm there are gold-bearing quartz veins which follow fissures in a dioritic and also in a granitic rock. Those to the northeast of the Arm are zinc blende and galena ores, occurring in white crystalline limestones of the Wales series. The Dolomi region is gold and silver bearing. The ore bodies are in part true fissure veins and possibly in part replacements in the white crystalline limestone. The Kitkun Bay region is a northern extension of the same class of deposits. In both regions the gold is in part free and in part combined.

In the South Arm of Cholmondeley Sound are found copper deposits which are similar in many ways to those of Niblack Anchorage. They occur as mineralized zones in a feldspathic schist. The Twelvemile Arm region has true fissure veins, which are similar to those of Thorne Arm. The ores are gold and silver, the former in part free milling. Some of these veins, like those of Thorne Arm, are closely associated with porphyry dikes. The Karta Bay deposits are probably a northwesterly extension of the belt.

The Skowl Arm, Kasaan Peninsula, and Tolstoi Bay regions contain copper deposits, chiefly sulphides, which are similar in character. These are in part irregular masses of ore contained in massive greenstones, and in part form better defined zones in schistose phases of the greenstone. In the Hetta Inlet region only the Copper Mountain deposits were examined. These, which yield high copper values, occur along the contacts of white crystalline limestone and intrusive rock masses.

The detailed descriptions which follow do not by any means include a complete list of all of the claims of the district. The work was so planned as to permit of the examination of those localities in the eastern part of the district, where the greatest developments had been made. During the progress of the work many claims of minor importance were examined because they lay near the route of travel, and descriptions of many such are included in this report. It is the province of the geologist to describe the types of the ore bodies, and the detailed descriptions of properties should be left to mining engineers and experts. In the Ketchikan district, however, the developments have been so insignificant, and our knowledge of the geology is so small, that the writer has been forced to present detailed descriptions in lieu of broad generalizations and conclusions.

## DESCRIPTIONS OF LOCALITIES.

### CLEVELAND PENINSULA.

*General description.*—The Cleveland Peninsula is the rugged land mass which separates Ernest Sound from Behm Canal (see Pl. II and fig. 1). The mountains which make up the peninsula are transverse to its longer axis and parallel to Clarence Strait and to the general strike of the bed rock.

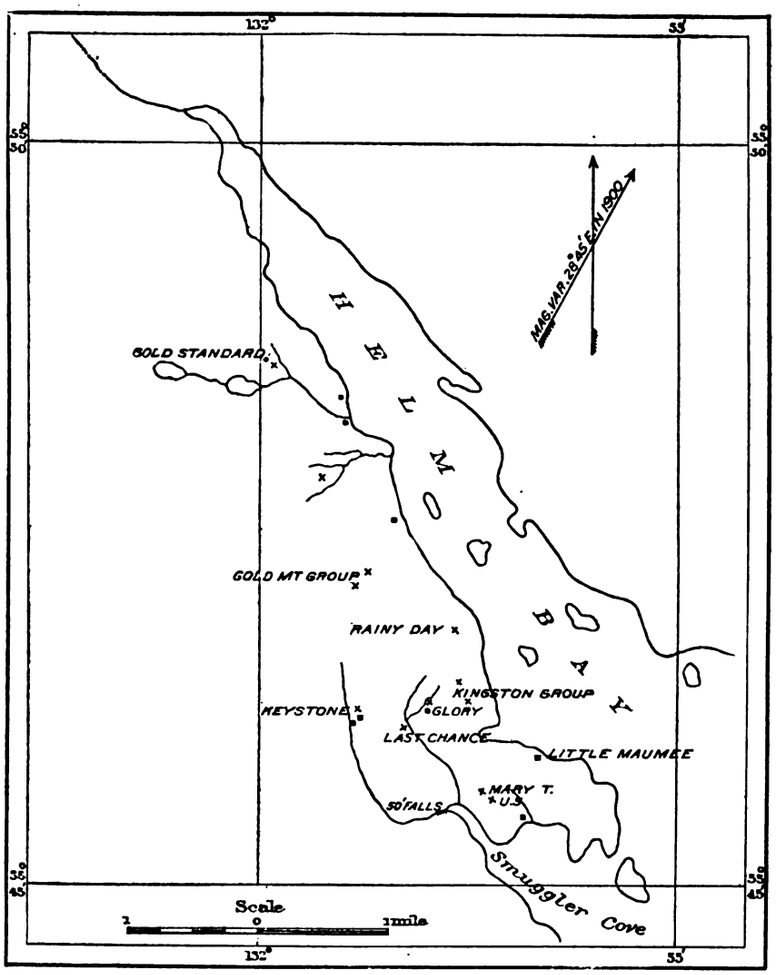


FIG. 1.—Sketch map of Cleveland Peninsula, showing claim locations.

The northern part of the peninsula is occupied by granitic rocks (see geologic map, Pl. II), which, near their southern boundary, are more or less gneissoid. To the southwest of the granite is a belt of closely folded argillites, with some calcareous beds, which belong to the Ketchikan series. Intercalated greenstone-

schists, derived from igneous rocks, are very plentiful in the slate series, occurring in belts up to half a mile in width. They consist chiefly of secondary minerals, chlorite, epidote, and actinolite, with occasionally some primary minerals, such as plagioclase, amphiboles, and pyroxenes. The foliation of the schists is parallel to that of the argillites. Previous to their deformation and metamorphism they were probably intercalated sills of diabases and allied rocks. The greenstones everywhere carry considerable pyrite. The argillites and associated greenstone-schists are intruded by massive dikes, which cut across the foliation, and which also carry considerable pyrite. There are also masses of greenish porphyritic rock, made up of plagioclase, amphibole, and pyroxene, which may be provisionally classed as diorites. West of Helm Bay there is a considerable mass of pyroxene-granite, whose outline is approximately indicated on the accompanying map.

The western part of the peninsula, which borders Clarence Strait, is formed of a green, porphyritic rock, which has been mapped as a part of the Kasaan greenstone. It is not unlike the porphyritic dikes which have been described.

Mining operations have thus far been confined to the southeast coast, on the southwest side of Helm Bay and Smuggler Cove. The values are chiefly gold, with some silver, and in some claims possibly copper. The gold deposits which have thus far been exploited are chiefly free milling. The common association of minerals is free gold, iron pyrite, with a little galena, and a quartz gangue. In some veins chalcopyrite and bornite occur as accessory minerals, as does also telluride. Prospectors report the occurrence of gold-bearing quartz veins on the north side of the peninsula, but these have not been developed.

The mineralized zone, as far as determined, includes a belt at least a mile in width lying on the west side of Helm Bay, which stretches in a northwest-southeast direction. In this zone at least half of the country rock is greenstone-schist. The results of the investigation seem to show that there are two distinct systems of quartz veins. The older system follows lines of fracture running about parallel to the foliation of the schists, which varies in direction from N. to N. 20° W.; the younger veins follow fractures running N. 20°–40° E. Movement took place after the deposition of the older quartz veins and previous to the deposition of the second series. As far as could be determined, the richest deposits occur where the two systems intersect. The first system of veins usually has fairly well-defined walls, while the second system sends off shoots into both walls. The ore bodies are for the most part mineralized zones in which the country rock has been sheared and brecciated and then permeated by the mineral-bearing solutions. In some of these deposits the gold is irregularly distributed in extraordinarily rich pockets; in others the ore is low grade but the distribution more uniform. Many beautiful specimens of native gold have been found in the region. In deposits of this nature it is very difficult to obtain commercial samples for assay. The pockety character of some of the ore bodies makes it desirable that they should be very carefully prospected before a large

being about $8, 5 per cent of which is in the concentrates. The values seem to be rather evenly distributed. The concentrates are valued at $140 a ton. In the mineralized zone are many irregular quartz veins and quartz blebs, and probably both generations of veins are represented. It is a source of great regret to the writer that he was not able to study this occurrence in greater detail.

The systematic manner in which this property has been developed reflects great credit on the superintendent, Mr. J. A. Bradley. He has deliberately gone to work to find out the size and value of the ore body before investing money in an expensive mining plant. Mr. Bradley's example might well be followed by many of the other property owners of the Ketchikan district. The locality is exceedingly favorable for cheap mining, and excellent water power is near at hand.

*Little Maumee claim.*—This name has been given to a small vein which cuts a porphyritic diorite on the west side of Helm Bay. The vein follows a shear zone in the diorite and is about 12 inches in width. It carries both copper and iron pyrite, and is said to carry gold values. At a number of other localities in this vicinity small veins are found in the diorite, or the diorite itself is found mineralized along shear zones. One of these mineralized diorites is said to have shown, on assay, a gold value of 96 cents. The general strike of these veins is nearly east and west.

*Kingston claims.*—This group of claims, on which no development has been made, is about a quarter of a mile from tide water, near the entrance to and on the west side of Helm Bay. The country rock is a chloritic schist associated with a graphitic schist. The ore body is a mineralized zone in chloritic schist, varying from 6 to 30 feet in width. In this mineralized zone vein quartz predominates, with some masses of the country rock. The widest quartz vein observed was about 6 feet. Assays of material from this group have shown variations in gold values of from $2.50 to $600.

*Rainy Day claim.*—About a half mile north of the Kingston group is a mass of granite-porphyry, a quarter to a half mile in width, apparently intrusive in black slate. The Rainy Day claim is located in the granite on a quartz vein which strikes northwest and southeast and which has a width of from 3 to 3½ feet. It is said to have been traced 300 to 500 feet, and carries pyrite and free gold. The occurrence is of interest as it shows that the quartz veins were introduced subsequent to the granite.

*Gold Mountain claims.*—This group is located west of Helm Bay, about three-fourths of a mile from tide water. A shaft 1,100 feet above tide water has been sunk to a depth of about 20 feet, and some stripping has been done elsewhere. The country rock is a chloritic schist, which strikes northeast and southwest, nearly at right angles to the veins which lie nearer to the entrance of the bay. The vein exposed in the shaft averages from 2 inches to 2 feet in width. It is irregular and sends out many stringers into the country rock. The assays range from $4

A number of veins have been stripped on adjacent claims which were not visited. These are said to strike about north and south. On the same property, about one-half mile south of the mine, there are quartz and calcite veins cutting a schistose diorite. These veins, which strike about north and south, are from 10 to 14 inches wide and carry free gold, with which some tellurides are associated. The values are said to run from $5 to $15.

TONGASS NARROWS.

*General description.*—Tongass Narrows is the waterway which separates Gravina from Revillagigedo Island (see Pl. II and fig. 2). Near its southern end

FIG. 2.—Sketch map of Tongass Narrows and George Inlet, showing claim locations.

Pennock Island divides the Narrows into two channels. The mountains on either side rise either directly from the shore line or from a narrow, rocky beach. They are parallel to the channel, and reach altitudes of 2,000 and 3,000 feet.

From a geologic standpoint this region can be considered a southern extension of the area lying adjacent to Helm Bay. Greenstone-schists outcrop on both sides of Tongass Narrows. Under the microscope this rock is seen to be an altered diabase. On either side of the greenstone-schist belt are argillites belonging to the Ketchikan series. Numerous dioritic dikes cut across the foliation of the schists,

uncommon in the greenstone-schists and in the argillaceous and arenaceous schists which form the country rock east of Ketchikan. Values of $10 in gold to the ton are reported.

*Birdseye claim.*—This is located on the beach, on the east side of Tongass Narrows, about 1½ miles southeast of Ketchikan, and was one of the first localities at which mining was done. The developments consist of a 35-foot shaft, which was filled with water when visited. The vein, which apparently consists of a series of lenticular quartz masses, occurs in a feldspathic rock, which is believed to be sedimentary. The feldspathic sediment lies between a belt of black slate and chloritic schist which belong to the Ketchikan series. Small stringers of quartz carrying pyrite are not uncommon in the black slate. It is said that the ore taken out at the Birdseye claim, which was obtained chiefly from the bowlders at the surface, yielded about $30 in gold to the ton.

*Bell claim.*—This claim, located on the east side of Gravina Island, adjacent to Tongass Narrows and nearly opposite the south end of Pennock Island, was also one of the earliest to be developed. The shaft, filled with water at the time the writer visited it, is about 50 feet deep, and a crosscut is said to be 40 feet in length. The bed rock is a chloritic schist. The ore body seems to have been a mineralized zone which carried many small veins of quartz and calcite. The veins cut across the foliation of the schist. These veins and blebs carried sulphurets, and the best assays are said to have yielded $18 in gold to the ton. The schist, which is itself mineralized, it is claimed will run from $1 to $2.

*Heckman's claim.*—This claim, on Gravina Island, adjacent to Tongass Narrows, about 1 mile southeast of the Bell claim, is practically a continuation of the same zone. The bed rock is a chloritic schist, with numerous quartz and calcite stringers and veins. The development consists of an open cut 30 feet wide, which is more or less mineralized throughout. The quartz and calcite veins carry iron pyrite. A mill test is said to have yielded $3.50 in gold.

*Easter claim.*—This is located near the upper end of Gravina Island, not far from the Spindle, and about half a mile inland from tide water. The group includes three claims, which lie along the strike of the vein. The development consists of a pit about 6 feet deep. The ore, which is a gold and iron-pyrite bearing quartz vein, with some arsenopyrite, is said to run from $3 to $400 per ton. As given by the owner the values of one lot of assays ranged from $157 to $301, and of a second lot from $7 to $301. The strike of the vein is about N. 70° W., with a dip of 70° N. The vein has been traced for 3,800 feet. The country rock is a much sheared clay slate and greenstone-schist, the latter forming the hanging wall. The foliation of the schist is cut by the vein, which seems to follow a fissure. At the time of the examination the prospect pit was filled with water, but it was stated that the vein is divided into two parts by a layer of blue slate. The upper vein is said to be 18 inches wide near the surface, and pinches to 8 inches in 10 feet. The second

of the quartz-schist at an angle of about 60°. The bed rock is nearly horizontal, dipping to the north. The shear zone in the cut has well-marked fault planes, and there is apparently some brecciation. The ore is galena and zinc blende.

THORNE ARM.

*General description.*—The upper end of Thorne Arm (see Pl. II and fig. 3), an embayment which cuts into the southern shore of Revillagigedo Island, has been

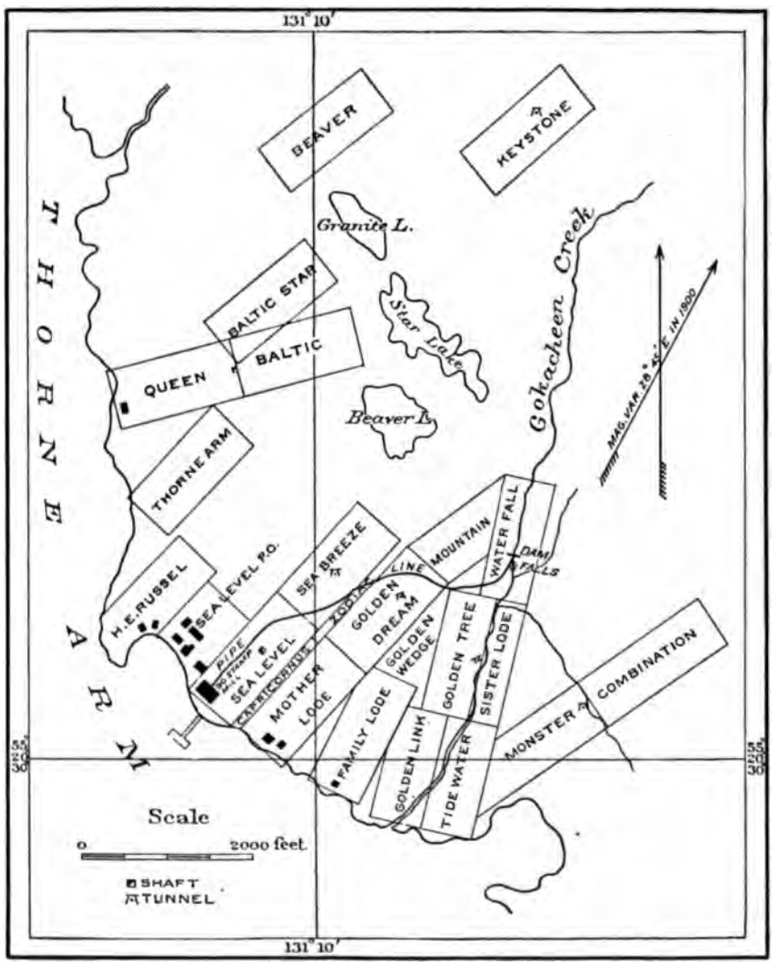


FIG. 3.—Sketch map of Thorne Arm, showing claim locations.

the scene of considerable mining activity. The inlet has a northerly-southerly course, transverse to the general trend of the adjacent mountains, which reach altitudes of 2,000 to 2,500 feet. Except at the delta mouths of some of the larger streams the shore line is abrupt and rocky.

The salient features of the geology are not complex, though but little is known of details. The western boundary of the Coast Range granite belt lies within a few miles of the upper end of Thorne Arm (see geologic map, Pl. II). To the west of the granite are the rocks of the Ketchikan series, which form the country rock of the upper half of the inlet. The sediments of this series are argillites, with some limestones. Both the phyllites and the limestones are considerably altered, and, as this metamorphism increases as the granite is approached, the alteration may be assigned to the contact metamorphism as well as the mechanical deformation caused by the intrusion of this vast granite mass. A number of smaller granitic stocks occur within the sedimentary belt. Most of them are too small for representation on the accompanying map (Pl. II), but one at the entrance to Thorne Arm covers a considerable area.

The Ketchikan series is typically made up of argillaceous and calcareous sediments, but in the Thorne Arm region it includes large amounts of igneous rocks. These are for the most part greenstone-schists, occurring as intercalated bands which have suffered the same deformation as the sediments. In many cases the igneous and sedimentary rocks are so intimately associated that it would be impossible to define their separate areas even with the most detailed work. The greenstone-schists are plainly igneous, and are chiefly altered diabasic rocks. Similar sheared greenstones also occur in belts, sometimes half a mile or more wide, in the Thorne Arm region. Massive dioritic rocks occur as more recent intrusions. These cut both the sediments and the greenstone-schists. Dikes of a bluish porphyritic rock form another series of intrusions, which are of great economic interest because of their intimate association with some of the ore bodies. These dikes were found cutting the greenstone-schists which form the country rock on some of the claims at the upper end of Thorne Arm. In the hand specimen this rock shows rounded porphyritic crystals in a bluish-gray groundmass. The more weathered varieties have a reddish color. The original character of this rock could not be determined, as it was only found in association with ore bodies and where it had been permeated with the ore-bearing solutions. In thin section the phenocrysts (porphyritic crystals) were found to be made up entirely of secondary minerals, chiefly quartz and calcite, with some muscovite. The groundmass (cement) consists essentially of a finer aggregate of the same minerals, together with various other secondary minerals, such as epidote and biotite No specific determination of this rock could be made, but it is probably an altered aporhyolite. In the following description it will be convenient to use the miners' terminology and refer to it as porphyry. Some basaltic rocks carrying the silicate mineral olivine, which are apparently surface flows, were observed in the vicinity. The areas occupied by these rocks are too small to be represented on the geologic map.

The mineral values of the Thorne Arm region lie in its gold- and silver-bearing quartz veins. The veins, which cut across the foliation of the country rock, vary in

trend from N. 20° to 45° E., and are usually persistent, with well-defined walls. They carry free gold, gold-bearing pyrite, and galena. Some are said to carry sphalerite, though this mineral was not observed by the writer. The gangue is usually quartz, with some calcite. While there are some very good prospects in the Thorne Arm region, there are many pyrite-carrying veins which contain only very small values.

*Sea Level mine.*—This property, which was among the first to be developed in the district, is located on the eastern shore, at the upper end of Thorne Arm. The country rock is chiefly greenstone-schist. It is made up of actinolite, chlorite, and quartz, often contains also garnet and some calcite, and is always impregnated with considerable pyrite. This altered igneous rock is associated with sedimentary rocks, which are chiefly calcareous schists. The strike of the bed rock is from north to N. 20° W., and the dip of the foliation is variable, but is most often steep to the northeast.

The ore at the Sea Level mine is found in and near two parallel veins which follow a 25-foot intrusive dike of bluish porphyry. In the area examined the veins do not leave the dike, which cuts across the foliation of the country rock. The course of the dike is about N. 40° E., and its dip, together with that of the quartz veins, is about 80° SE. The veins are not quite parallel, the average distance between them in the first level of the mine being probably 15 feet. Near the shaft the easterly vein is about 5 feet wide, the westerly about 2 feet wide, but these dimensions do not represent the full width of the ore bodies, as the dike rock is itself heavily mineralized and carries gold values near the vein. The quartz veins themselves are well defined, but send numerous offshoots into both walls, which accounts for the dike being more or less mineralized throughout its extent. However, it is said to carry commercial values near the vein only. Some of the quartz stringers penetrate the chloritic schists which form the walls of the dike, and, while they contain pyrite, it is said that they carry no gold values outside of the porphyry. The quartz veins themselves do not seem to have suffered deformation, except near the north end of the claim, where the quartz is somewhat crushed. The dike and veins are traceable by surface outcrops for about 1,200 feet on the Sea Level claim, and the same zone of mineralization extends northward into the Sea Breeze property.

The ore is free gold, gold-bearing iron pyrite, and galena. The gangue is usually white quartz, with occasionally some calcite. The pyrite occurs as well-formed isolated cubes and as granular aggregates. In the latter form it seems to carry the higher gold values. The preliminary development of the mine has yielded a good deal of specimen gold. The average of the ore body is said to run $5.35 in gold values, but it is not uncommon to get assay returns of $20 to $30. The concentrates are said to run from $300 to $500 a ton. Some fragments, chipped more or less at random from the vein by the writer, were assayed by Dr. E. T. Allen, of the Geological Survey, and found to contain $65.12 in gold and 3.25 ounces of silver to the ton.

The development at the time of visit consisted of a small steam hoist over a shaft 125 feet deep, with tunnels 400 and 500 feet in length, respectively, at the 50- and 125-foot levels, both having several crosscuts. Besides the underground workings there were also some open cuts at various points along the outcrop of the vein. The results of this development seem to have satisfied the owners that they were warranted in making a considerable investment, as they are now installing the most extensive mining plant in the Ketchikan district. According to latest reports the shaft is being enlarged to a 3-compartment working shaft. The collar of this shaft is about 100 feet above tide water. The steam hoisting equipment has been installed and a 30-stamp mill has been erected on the beach, together with an ore crusher and 6 Frue vanners. The stamp mill is connected with the shaft by a rail tramway operated by gravity. The power for the mill is furnished by 6 pelton wheels of different sizes, the water being brought from the falls a mile distant.

*Sea Breeze claim.*—This vein is a northeasterly extension of the one already described, and can be traced almost continuously through the two properties. Near the southern end of the claim the vein is faulted about 10 feet. The workings consist of one open cut. The country rock at the cut is a greenstone, similar in character to that at the Sea Level, only more massive. The vein is 6 to 7 feet wide, and carries iron pyrite, gold, and some galena. Where the sulphurets are plentiful the vein carries high values. The gangue mineral is chiefly quartz. The porphyry in this case occurs only to the southeast of the vein, while on the northwest it comes directly in contact with the greenstone-schist. In this respect the Sea Breeze vein differs from the Sea Level, where the porphyry forms the casing. No definite information was obtained in regard to values, but it is reported that while there is some rich ore the values are more spotted than on the Sea Level claim.

*Golden Dream claim.*—This claim is about a mile from the beach, and adjacent to the Sea Breeze. The vein is nearly 20 feet in width, and is made up of white quartz and calcite, carrying some sulphurets. It seems to be a large lens, which pinches out, and extends as smaller quartz lenses that carry pyrite and zinc blende. The country rock is greenstone-schist. It has been traced on the surface about 300 feet by the outcrop of a succession of lenticular quartz masses. The strike is N. 70° E., and the vein cuts across the foliation of the schist. Assays are said to have run as high as $4 in gold.

*Mother Lode claim.*—This vein runs about N. 25° E., and consists of 8 feet of glassy quartz, which carries pyrite and a little gold. Picked samples gave assay values of about $30. The claim lies adjacent to the Sea Level claim, and the vein has been traced 400 to 500 feet. The country rock is diabase-schist and quartz-calcite-schist.

*Golden Tree claim.*—This claim, which has received but very little development, is located on Gokacheen Creek, about a mile from the beach. It consists of a series of lenses that carry small pockets of gold, some of which run very high in gold values. The quartz veins are about 6 inches in width, and cut across the foliation

of the country rock, which is quartz-calcite-schist. The strike of the vein is about N. 70° W.

*Tide Water claim.*—This is a well-defined vein, 18 inches in width, situated close to the Golden Tree. It cuts diabase-schist, and carries a small amount of free gold.

*Monster claim.*—The ore body is a large pegmatite dike, having a width of 12 to 20 feet. It has been regarded as a quartz vein by the prospectors, but under the microscope is seen to be made up of an intergrowth of quartz and feldspar. Pyrite is everywhere disseminated through it, but its gold values are said to be very low. The wall rock is a diabase-schist. Near the contact the schist itself carries considerable pyrite.

*Keystone claim.*—This claim lies to the east of the upper end of Thorne Arm. Unfortunately the writer was unable to visit it. It is said to be about 1½ miles from the beach, and to carry pyrite, galena, and zinc blende. The country rock is granite, and the vein is said to be 5 feet in width and to have been traced 150 to 200 yards. The assays are said to show a gold content of $12. Since the writer visited the region the Ketchikan Gold Company, after further prospecting, has undertaken the systematic development of this claim.

### SEAL BAY AND DALL HEAD.

*General description.*—Considerable prospecting has been done in a copper-bearing region lying near the southern end of Gravina Island, where the first discoveries were made in 1898. The prospects of this locality are divisible into two groups, one lying adjacent to Seal Bay, the other near Dall Head. As the geologic conditions are the same in both regions they will be described together.

A bold ridge, with a north-south trend and an altitude of 2,000 feet, stretches along the western shore of Gravina Island. Near the southern end of the island this ridge impinges on a group of mountains which trend northeast and southwest, parallel to the southeastern coast line of the island. The mountains in this second group have very abrupt slopes. Though time did not permit the study of the structural features of these mountains in detail, their outline and their relation to the north-south ridge are strongly suggestive of considerable faulting, especially as small faults are of very common occurrence.

Seal Bay is a minor indentation of the southeastern coast line of the island (see Pl. II and fig. 4). At low tide a reef of rocks almost completely cuts off the bay from the strait. At high tide there is no shelter from the southerly storms which sweep northward from Dixon Entrance. Dall Bay, a few miles to the south, is a deeper indentation, and has a small, fairly good harbor. Some claims have also been opened up on the Clarence Strait side of the island, nearly due west from Dall Bay. Although the coast line is there very irregular, there is no shelter except for small boats.

The bed rock of this region is chiefly greenstone-schists, which are intruded into a calcareous series. Both the igneous and the sedimentary rocks have been

intensely folded. The calcareous beds, which are in part of Devonian age, have been provisionally assigned to the Vallenar series. This correlation has been made on a very slender foundation of fact, and may eventually be overthrown.

After the deformation of the calcareous schists and greenstone-schists, a considerable injection of pegmatite in the form of large dikes took place. This intrusion was succeeded by a period of erosion, when heavy conglomerates were deposited

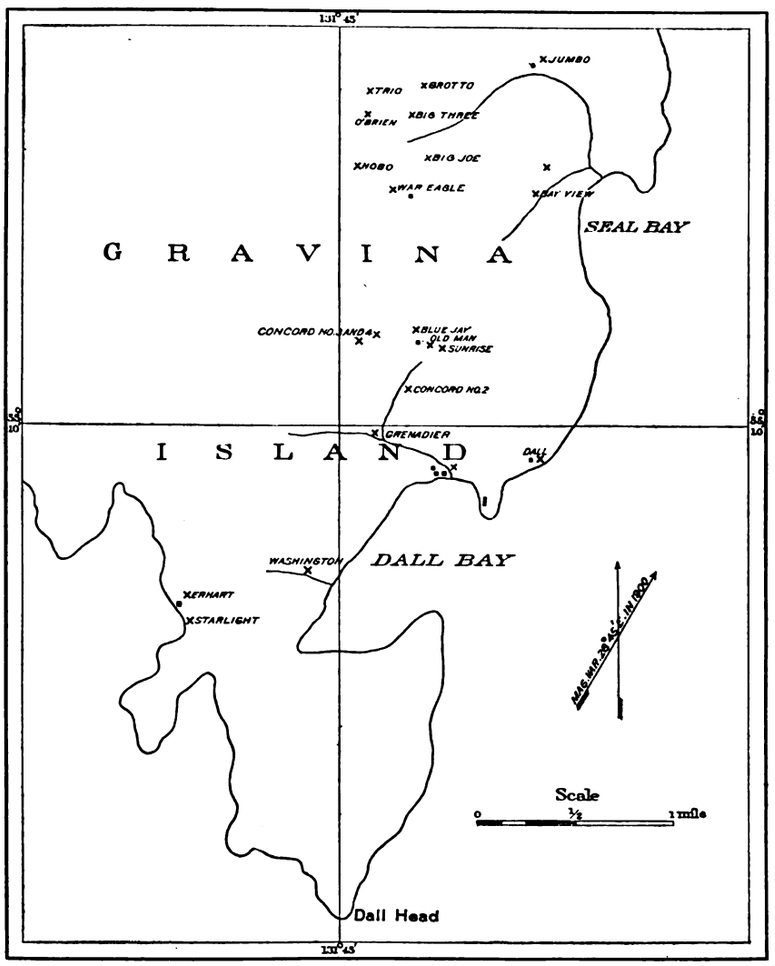


FIG. 4.—Sketch map of Seal Bay and Dall Head, showing claim locations.

unconformably on the schistose rocks. With the conglomerates there are some black slates, and these detrital beds have been named the Gravina series, and are believed to be Mesozoic. The rocks of the Gravina series have also suffered intense deformation and are closely folded and faulted. The strike is usually about north and south and the dip steep toward the east.

The ore bodies are found along zones of brecciation, which most commonly occur near the contact of the pegmatite and greenstone-schists. In these zones the country rock has been broken by fault movement. The brecciated zones have been penetrated by the mineralizing solutions which have recemented the broken rock.

The ore is chiefly chalcopyrite, usually accompanied by considerable pyrite, and usually carrying some gold values. The gangue is chiefly quartz, often with some jasper or calcite. Sphalerite (zinc blende) is commonly associated with the copper pyrite. The ore bodies include some small veins which are very rich and some large deposits which are of low grade, but are probably more uniform in their mode of occurrence, and therefore of greater importance from a commercial standpoint. During a rather hasty visit the writer found only a few of the owners or their representatives at these properties, and their absence prevented a study of many of the occurrences with as much thoroughness as their importance demanded, and also precluded the collection of exact information in regard to values.

*Seal Bay.*—Two test pits have been sunk on the beach close to tide water. The more westerly one is in a green, contorted schist which carries some pyrite. The more easterly is in a mineralized pegmatite which carries copper pyrite with a quartz and calcite gangue.

*Bay View claims.*—These claims are about a half mile to the west of Seal Bay. At No. 2 an open cut of 20 feet exposes a dark-green diabase-schist, and, next to and grading into it, a brecciated form of the same rock, which has been recemented by quartz and some calcite. With this infiltrated quartz occur iron and copper pyrite and some bornite. The mineralization occurs at intervals for 30 to 40 feet. At the No. 3 claim of this group there is a 20-foot drift. The bed rock is a dark-green schist, which is slickensided and brecciated, with a recementation by ore-bearing solutions. One fault zone runs N. 30° E., another about N. 60° W. The ore from this locality is copper and iron pyrite, with some zinc blende. The drift was driven along a vein carrying pyrite, about a foot in width, which runs about N. 60° W. The Bay View claims belong to the Victory Mining Company.

*War Eagle claim.*—At this locality there is a shaft, probably 40 feet deep, and near at hand two tunnels, which are about 100 feet apart vertically. The country rock is a greenstone-schist, which has been sheared and brecciated, and the ore occurs along the shear zones. Near the breast of the lower tunnel about 3 feet of the breccia and ore are shown. The strike of the vein is approximately N. 30° E. The fault plane dips about 85° E. and is approximately parallel to the strike. The ore is a chalcopyrite and is said to carry gold values. This claim, together with the Big Joe, where an open cut exposes the extension of the same mineral-bearing zone, belongs to the Patterson Company. The same company also owns the Hobo claim, which joins the War Eagle on the west. The latter was not visited.

*Grotto claim.*—This claim, together with the O'Brien, Trio, and the Big Three, which lie to the north, belong to the Victory Mining Company. When the exami-

nation was made there was no one on the property, but since then developments have been actively pushed.

The mine workings were found to consist of a tunnel about 100 feet long, located about 600 feet above tide, and a second tunnel, 50 feet higher and 30 feet long. The lower tunnel cuts across the foliation of the greenstone-schist which forms the country rock. The greenstone-schist is all somewhat mineralized, but probably does not carry values, except along shear zones, where the mineralization has been more intense. These shear zones occur at irregular intervals in the inner 30 feet of the tunnel, which is near a mass of intrusive pegmatite. The upper tunnel has penetrated a brecciated greenstone-schist, which is more or less mineralized for the full length of the tunnel, or about 30 feet.

Since our examination the lower tunnel has been driven 100 feet farther, and the company is reported to be now drifting on the ore body. It would seem from this that the writer's observations were at fault and that the mineralized zone observed at a depth of 100 feet in the lower tunnel was not the same ore body which is exposed in the upper tunnel. The company reports the lead to be 25 feet wide where the tunnel intersects it. The croppings average 11 per cent copper across 5 feet. The walls of the ore body where the drift is being driven are said to be well defined. About one-fourth of a mile in a northerly direction from the lower tunnel a small shaft, probably 50 feet deep, had been sunk, at the time of our visit, in some mineralized schists.

*Jumbo claim.*—This is about half a mile from the beach and not more than 50 feet above tide water. A small crosscut exposes 5 to 10 feet of a zone in part heavily mineralized with copper and iron pyrite. In its occurrence it is similar in character to the ore bodies already described. The opening is in a flat, and there are no outcrops in the vicinity.

*Rossland and Deer Park Mining Company.*—The claims belonging to this company are adjacent to Dall Bay. The company has erected several substantial buildings and has sunk two shafts, with crosscuts, and a number of test pits. The two shafts are in the southern corner of Dall No. 4. One is located just at tide water, and said to be about 30 feet deep; the other is 20 feet higher, and 50 or 60 feet deep, with a crosscut at the bottom. Both of these shafts were filled with water when visited. The deeper shaft is provided with a steam hoist. The ore observed on the dump is chalcopyrite, with quartz gangue. The waste dump contained fragments of mineralized pegmatite and also of chloritic greenstone-schist. About 50 feet to the east of the shaft is an outcrop of brecciated porphyry.

In a small crosscut located on Dall No. 5, near the mess house, is exposed a red pegmatitic rock. Close at hand is a mass of diabase-schist. The pegmatite is more or less mineralized.

It was very unfortunate that the mine workings were not accessible when visited. The interruption of the development of the property was because of a lawsuit.

Enough was seen by the writer to convince him that the ore body in its general character is similar to those which have been described in adjacent localities. The position of the ore body makes it more difficult to work than those where the topographic conditions permit of crosscutting by tunnels.

The writer is indebted to Mr. C. H. Hunt, manager of the Rossland and Deer Park Mining Company, for the following information, which is extracted from a letter dated Portland, Oreg., December 27, 1901:

"I regret that no one representing the interest of the company was on the ground at the time of your visit, as the real merits of the property could be shown only by one familiar with the ground, to point out the places where the ledge is exposed for a distance of several hundred feet from the beach in a northerly direction. There are also several places where considerable prospecting has been done other than at the shafts which you visited. At all the points where prospecting has been done on this ledge the same character of ore has been found, showing that the ore body is continuous. * * *

"From the many assays made from time to time, values were shown in gold, copper, and silver, fluctuating sometimes as high as 30 per cent copper, $10 in gold and $3 in silver. This showing was from ore taken from the ore shoot, the same in both shafts, beginning at the surface, gradually increasing in strength to the depth of 60 feet in one shaft and 100 feet in another. In the latter a crosscut was run at a depth of 90 feet a distance of 25 feet, showing a defined ledge thoroughly mineralized. In the pay shoot, which is 3 feet wide, the ore is highly mineralized. As I have stated, the values change, but a careful estimate made from the whole shows an average of 11 per cent copper, $6 in gold, with slight values in silver."

*Washington claim.*—This is located about three-fourths mile west of Dall Bay. A prospecting drift about 20 feet long is the only development work. The country rock is a reddish pegmatite, which is cut by a diabase dike and rendered more or less schistose. The diabase in this instance is plainly the later intrusion. The relations between the acid and basic rocks in this locality seem to be different from those studied elsewhere. The mineralized zone occurs along the contact of the diabase and the pegmatite, along which there has been shearing, and both rock masses have been more or less brecciated. In this brecciated zone some iron and copper pyrite is developed, with quartz and jasper gangue.

*Apex group.*—This group, embracing about a dozen claims, lies a mile to the north of Dall Bay. The highest is on the top of the mountain, 1,000 feet above tide water. The ore bodies contain chalcopyrite with zinc blende, and often carry gold values.

On the Concord No. 2 a tunnel has been driven for about 10 feet. The ore is mineralized breccia, occurring at the contact of coarse pegmatite and banded green schist. It contains chalcopyrite, with quartz and calcite gangue and a little manganese.

The uppermost claims of the group, Concord Nos. 3 and 4, are near the top of the mountain. These deposits lie at the contact of the greenstone-schist and

pegmatite. The rocks dip steeply 80° SE. One open cut shows 2 feet and another 18 inches to 2 feet of pyrite and zinc blende. The veins cut the greenstone-schist. The walls of this latter vein are silicified.

On the Blue Jay claim of this group a tunnel has been driven about 50 feet. The tunnel intersects some brecciated zones near the contacts of greenstone and pegmatite, along which mineralization has taken place.

At the Old Man claim a mineralized zone several feet in thickness, carrying copper pyrite, is exposed in a small open cut. It is in a brecciated zone and carries considerable zinc blende.

A quarter of a mile to the east of the Old Man is the Sunrise vein, which has a thickness of 12 to 18 inches. It has been traced on the surface for several hundred feet. Its strike is N. 75° W., dip S. 80°. Near the contact with the greenstone-schist the country rock is a pegmatite. This vein seems to be better defined than many of the others, and shows a beautiful mass of chalcopyrite ore. The ore is said to carry values of $72, which is chiefly in copper, with a little silver and gold.

*Grenadier claim.*—This property is located about 1 mile west of the upper end of Dall Bay. A prospecting cut about 10 feet deep shows greenstones, schists, and pegmatite more or less brecciated near the contact. Some mineralization has taken place along the shear zones.

*Erhart's claim.*—This locality is on the west side of Gravina Island, nearly opposite Dall Bay. The name of the claim could not be learned, so it has been designated by the name of the owner. An open cut has exposed a small vein, which is apparently in a shear zone of porphyritic rock. The mineralization extends over a width of 4 to 5 feet, but the richer parts of the vein are less than 2 feet in thickness. The vein is rather ill defined. The ore is copper pyrite.

*Starlight claim.*—This locality is half a mile to the east of Erhart's claim. Here a tunnel has been opened up for about 50 feet. The ore body occupies a brecciated zone about 3 feet in thickness in a porphyritic rock. The ore is chiefly chalcopyrite, with calcite and quartz gangue.

### VALLENAR BAY.

*General description.*—Vallenar Bay is an embayment in the northwestern shore of Gravina Island (see Pl. II). It affords good shelter from southerly storms, but is not protected from the north or west. Some developments have been made on the bay at the Six Point property, and some at a locality about 3 miles south of the bay, lying adjacent to the strait. The bed rock of the shores of the bay includes some limestone and quartzite, probably of Devonian age, overlain by fragmental rocks which are probably tuffs, associated with carbonaceous slates. These beds have been grouped together and called the Vallenar series.

The so-called Six Point property has received some development, but has apparently been abandoned. The workings consist of a three-compartment shaft and some

drifts, which were filled with water when visited. As far as could be determined, the ore body lies along the contact of a slaty limestone and quartzite and an intrusive rock. The intrusive is considerably altered, but seems to have been of a diabasic character. Along this contact there has been considerable shearing and brecciation, and subsequently mineralization has taken place. The ore is chiefly pyrite and the gangue chiefly quartz.

At a locality about 3 miles south of Vallenar Bay, on the west coast of Gravina Island and 200 yards from the shore, a tunnel has been driven about 50 feet. This tunnel follows a shear zone which is in part mineralized. A vein carrying quartz and pyrite seems to be continuous in this mineralized zone, but swells out and narrows down, leaving a series of lenses connected by very small veins. At the face of the drift the vein is about 2 inches wide. The country rock on both sides of the vein is a sheared diabase, intrusive in graphitic slates, which are exposed close by. The mineralization is not entirely confined to the vein, but also permeates both walls of the diabase-schist. The name of this claim was not learned.

### NIBLACK ANCHORAGE.

*General description.*—Niblack Anchorage is an almost landlocked harbor on the southeastern coast of Prince of Wales Island, and is connected with Moira Sound by a waterway which permits of the entrance of the largest ships (see Pl. II and fig. 5). It is bordered on the north and south by mountains, which rise abruptly almost from the water's edge to altitudes of 2,000 and 2,500 feet. The bed rock along the shores is chiefly of igneous origin, but has suffered intense deformation, being rendered schistose, and in many ways resembling sedimentary beds. These igneous rocks are intrusive in the Wales series, which in adjacent regions consists chiefly of white crystalline limestone. The limestone itself is found to the north and south, but does not outcrop near the anchorage. Immediately north of Niblack there is a belt of siliceous schists, which are also a part of the Wales series. Greenstones outcrop on both shores of the inlet. In their more massive phases these rocks are dioritic in character, while the schistose phases are made up chiefly of chlorite, actinolite, and quartz, with other secondary minerals. The greenstones are believed to be intrusive in the sedimentary beds. To the south of this greenstone-schist belt is a zone of quartz-sericite-schist, whose southern boundary was not determined. These quartz-sericite-schists are typically bluish white, but near their contact with the greenstone-schist they contain considerable chlorite, and then it becomes difficult to distinguish the two rock types. The intrusive character of the sericite-schists in the greenstones was definitely established. The sericite-schist is believed to be an altered rhyolite. The strike of the foliation of the schists is northwest and southeast, and the dip predominantly steep to the southwest.

The ore bodies occur in both the greenstone-schist and the quartz-sericite-schist, and include veins and mineralized zones. The former veins carry the richest

ore, but the mineralized zones are more extensive and are probably of greater commercial importance. Both forms of deposit are, however, sometimes found in the same ore body. The ore is covellite, chalcopyrite, iron pyrite, gold, and a little galena. While they are primarily copper deposits, they often contain such large gold values that they could be worked for gold alone.

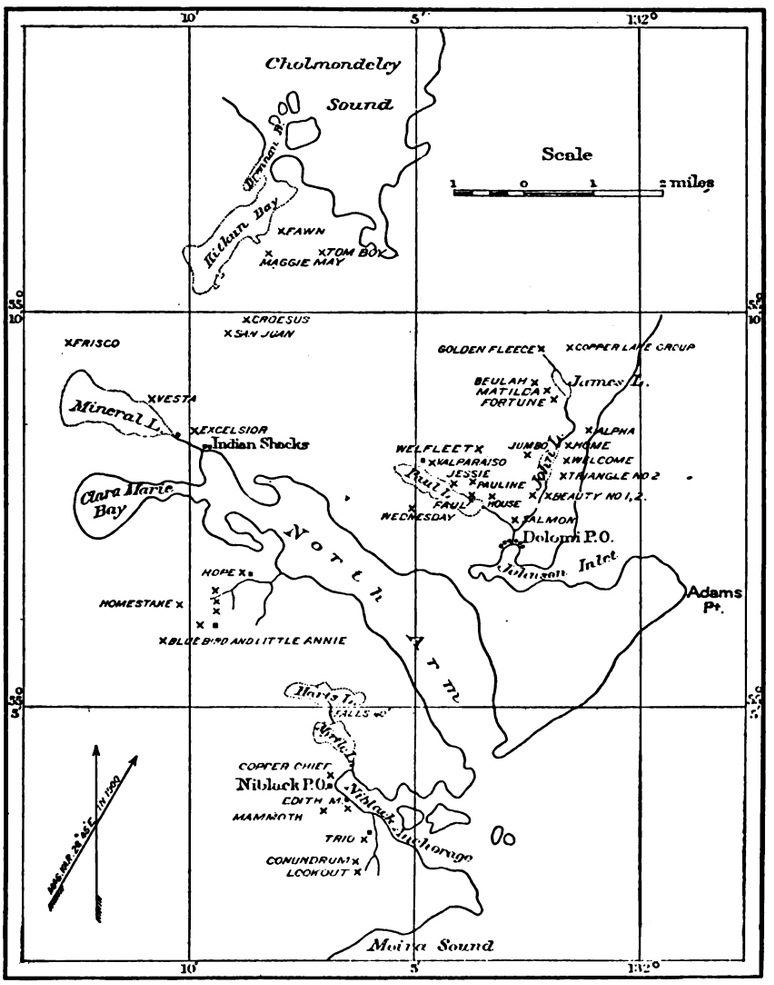


FIG. 5.—Sketch map of Kitkun Bay, Dolomi, North Arm, and Niblack Anchorage, showing claim locations.

*Lookout group.*—This is a group of six claims, controlled by one company, which lies to the south of and adjacent to Niblack Anchorage. The ore deposits on these claims are all similar in character, being mineralized quartz-sericite-schists, which carry a considerable percentage of copper pyrite and also of gold, together with iron pyrite. The character of this quartz-sericite-schist has already

been described. The schist is usually somewhat mineralized, but this mineralization is more intense along certain zones, which afford the commercial ore bodies.

A day was spent in visiting the various claims of this group. At the time of the examination the developments consisted of one tunnel and a number of open cuts. Within the zone are bands or veins of covellite, copper, and iron pyrite, with gold-bearing vein quartz. A sample taken across one of these bands, which had a width of about 15 feet, was assayed by Dr. Edward Fink, of Milwaukee, Wis., and gave the following returns: Copper, 5.2 per cent; gold, 0.20 ounce; silver, 2.31 ounces.

This ore body has only been stripped, so that we do not know what its character would be below the leaching action of water, but it is not likely that the values decrease.

The Conundrum claim has been opened by a tunnel about 30 feet long, of which about 25 feet are impregnated with iron and some copper pyrite. At this locality both chloritic schists and quartz-sericite-schists are exposed, and both are mineralized. The mineralized zone carries considerable quartz in places, and wherever the quartz is present it is accompanied by higher gold values. About 50 feet above the tunnel is an open cut, exposing 25 feet of mineralized zone, about 10 feet of which carries 9 per cent copper. The strike is N. 45° W. The dip is about 75° N.

One hundred feet higher, at an altitude of about 1,600 feet, on Lookout claim proper, an open cut shows a large mass of mineralized schist. This is made up largely of quartz and feldspar, and pyrites are pretty well disseminated. The country rock away from the zone is a foliated feldspar schist, similar in character to the ore except for the absence of pyrite. This upper mineralized zone is about 300 feet wide. Another series of assays, made from what may have been picked samples from this lead, showed values of 9 per cent in copper and from $4 to $8 in gold. Slipping planes are everywhere present in the ore body, and masses of covellite, copper, and iron pyrite ore, varying from a few inches up to a foot or two in width, alternate with chloritic schist lenses and bands. Along the walls of these bands of ore evidence of movement is always noticeable. The schist is highly silicified in bands parallel to the ore. Quartz blebs, carrying iron pyrite, occur cutting across the foliation of the schist, but are not found cutting the pyrite ore, and seem to belong to the same period of intrusion.

Near the western margin of this exposure the material passes into a metamorphic conglomerate. The pebbles of this conglomerate are largely of the feldspathic rock and of quartz. Some of the pebbles are well rounded, and there seems to be no doubt of the sedimentary character of this rock. The cement of the conglomerate is chloritic. The conglomerate was evidently formed previous to the deposition of the ore, as the ores penetrate the pebbles. The matrix is chiefly iron pyrite, chalcopyrite, covellite, chlorite, and quartz. It was unfortunate

that this peculiar conglomerate could not have received further study, as its position and origin are exceedingly puzzling.

Near and including this conglomerate is a mineralized zone, about 6 feet in width, which was sampled and assayed by Dr. Edward Fink with the following results: Copper, 2.69 per cent; gold, 0.12 ounce; silver, 1.3 ounces.

The Mammoth claim of this group is 500 feet above tide water, to the north of and adjacent to the Lookout claim. The mineralized zone is here about 20 feet wide. Copper and iron pyrite and covellite occur in bands and also disseminated through the rock. The widest band of fairly pure ore is 3 feet. This mineralized zone is said to have been traced for 500 feet, and it is believed to be an extension of the Lookout ore body. Chlorite-schist lies to the west of the ore body and forms the foot wall. The contact relations show that the quartz-sericite-schist is intrusive.

The Lookout group of claims is well located for development. The ore body is very large, and though not of high grade, it offers very good opportunities for exploitation. Its topographic position permits of its being mined at low cost. The physical character of the ore makes it well adapted for concentration. A water power, controlled by the same company, to the north of Niblack Anchorage could be converted into electric power, and would be ample for the purposes of mining and reduction.

*Trio claims* —This group, comprising several claims, lies to the north of the Conundrum. Some preliminary developments have been made at various localities. At one place visited a crosscut exposes an ore body about 10 feet in width. The ore is similar in character to that of the Lookout group, and carries both copper and gold.

This same belt of deposits is said to extend to the south, toward Moira Sound, and many claims have been staked in this region; but little development work has been done, and the party's time was too limited to visit these claims. The best information obtainable went to show that the ore bodies were similar in character to those of the Lookout.

*Copper Chief claim.*—This property lies adjacent to the west end of Niblack Anchorage. A shaft about 60 feet deep has been put down near the beach, but was filled with water when visited. The country rock is a greenstone-schist, which at the shaft is heavily mineralized for a width of 20 feet or more. The strike is about north and south, and the dip is 80° E. The ore is chiefly chalcopyrite, and appears to be of excellent quality, but is not so good for concentration as that of the Lookout claims. The mineralization is in irregular zones, with included horses of greenstone. A crosscut about 100 feet beyond the shaft shows a mineralized zone nearly 60 feet wide. The money spent on this claim was unfortunately used in sinking a shaft almost at tide water. Assays of the ore are said to have run as high as $42 in gold and copper values, of which $7 or $8 was in gold.

*Edith M. claim* —This property is located close to the beach on the south side of Niblack Anchorage. A 20-foot tunnel has been driven into a mineralized

been described. The schist is usually somewhat mineraliz
is more intense along certain zones, which afford the c

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exposure of granite 12 feet or more in width,
high as $38 to the ton.

greenstone-schist. A zone of iron and copper pyrite about a foot in width is exposed in the tunnel, and is said to carry $5 in gold and copper values. Another zone, about 8 feet in width, carries chiefly iron pyrite. A second mineralized zone is said to occur on the same claim.

NORTH ARM OF MOIRA SOUND.

*General description.*—This is an indentation of the southeastern coast of Prince of Wales Island, situated just north of Niblack Anchorage (see fig. 5). A belt of limestone associated with intrusive greenstones is found outcropping on both shores of this arm. The general strike is in a northwesterly direction. South of this limestone belt is an area of granite. The greenstones are usually schistose, though sometimes massive. The limestones belong to the Wales series, and the greenstones are intrusive in them, and both have been closely folded. Massive dioritic rocks also occur in some abundance. The ore bodies are of two types: First, quartz veins, which carry gold values, and which cut chiefly the dioritic rocks, but also cut the granite; second, veins found in the limestones. The ores of these are chiefly galena, sphalerite (zinc blende), and some copper pyrite. At one locality chalcocite was found.

*Homestake claim.*—This is located about 1½ miles to the south of the North Arm. The developments consist of an open cut. The country rock is an altered granite, which is cut by a porphyritic dike, andesitic in character. The ore body consists of a zone 6 feet in width, in which are small stringers of quartz carrying iron pyrite. These small veins are usually less than 1 inch in width, but widen out to 3 or 4 inches in places. The rock itself appears to be mineralized. No data were obtained in regard to the values, which are probably all in gold. The claim is located about 1,200 feet above tide water.

*Bluebird and Little Annie claims.*—These claims are about 1½ miles to the south of the Homestake. They were not visited, but the following information was obtained from Mr. John G. Westlake. The ore is said to occur at a contact of chloritic schist and granite. The ore body consists of 5 or 6 feet of smoky vein quartz, and assays show it to run $40 to $60 in gold. A specimen obtained from Mr. Westlake carries visible free gold.

*Hope claim.*—This claim is about half a mile northwest of the North Arm. The country rock is a porphyritic diorite, very highly silicified. A tunnel about 20 feet long has been driven on the vein, which consists of white quartz containing iron pyrite, some free gold, and a little chalcopyrite. The vein is about 2 feet in width at its widest part, but it narrows down again to a few inches and then broadens out. Two systems of jointing determine the position of the quartz veins. Near the surface an assay of the vein showed $40 in gold. This vein occurs in a shear zone which cuts the foliation of the country rock. Two hundred feet above the tunnel is a small exposure of granite 12 feet or more in width, which is said to carry gold values as high as $38 to the ton.

*Excelsior claim.*—This property is about 1 mile to the west of the head of North Arm, near Mineral Lake. It consists of a mineralized zone, 10 to 12 feet wide, in white crystalline limestone. This mineralized zone contains two veins of iron and copper pyrite, one about 2 feet and one about 3 feet in width. One hundred yards beyond the first exposure a crosscut opens up the same vein with a width of 3 feet. The ore is iron and copper pyrite. The limestone lying adjacent to the ore shows evidence of faulting and shear zones.

*Vesta claim.*—This is located about 2 miles to the west of the North Arm, on Mineral Lake. A tunnel 30 feet in length has been driven in white crystalline limestone. The ore body is a mineralized chloritic schist, which is contained between limestone walls. The ore is iron and copper pyrite.

*Frisco claim.*—This property is about 2 miles farther west and half a mile from the western end of Mineral Lake. It consists of a mineralized zone 8 feet wide, carrying zinc blende, iron and copper pyrite, and galena. It has been stripped at several places.

DOLOMI.

*General description.*—Under this heading the mining region adjacent to the town of Dolomi will be considered. The town of Dolomi, which included a store, a small wharf, sawmill, and post-office when visited, is well located, on Johnsons Inlet, a minor indentation of the eastern coast line of Prince of Wales Island, which affords a fair anchorage (see Pl. II and fig. 5). The ore bodies thus far discovered nearly all lie in the drainage basin of a stream which flows into the head of the inlet. Several lakes drain into this stream. The valleys are broad, and the mountains, which rise to 1,800 feet, have rather gentle slopes. The shore line and the surface are less rugged than in districts previously described. The rocks are chiefly limestones containing some magnesia, usually highly crystalline, striking in a northwesterly-southeasterly direction. These limestones, with which some graphitic phyllites are associated, belong to the Wales series, and are probably coextensive with those of Kitkun Bay, an arm of Cholmondeley Sound, which lies to the northwest. They also form a part of the same belt which has been described in the region of the North Arm of Moira Sound. The series is closely folded, and contains many intrusive greenstones, which have been usually rendered schistose. Lithologically the limestone varies from a blue, semicrystalline rock to one which is white and coarsely crystalline. The ore bodies of this region were among the first to be exploited in the district, the first prospecting work having been done in 1898. They are quartz veins which cut the foliation of the country rock, and must be for the most part regarded as true fissure veins. The ores, which are free milling for the most part, carry gold, iron pyrite, galena, and sometimes chalcopyrite and tetrahedrite (gray copper). In the Golden Fleece mine the relation of the ore body to the country rock suggests that the vein may be in part a replacement.

*Salmon claim.*—This is located about a quarter of a mile north of Dolomi. The vein has been opened up by a small crosscut and a prospecting pit. The wall rock is crystalline limestone, which is much sheared. The vein is 5 feet wide at the surface, and pinches down to 1 foot at the bottom of the pit. The gangue is chiefly bluish quartz, and carries free gold, iron pyrite, and galena. The average assay is said to run $8 to the ton, the lowest being $4 and the highest $22.

*Beauty claims.*—This group includes two claims about half a mile north of Dolomi, lying adjacent to the Salmon claim. Beauty No. 2 shows a mineralized quartz vein, 12 to 18 inches in thickness, in a micaceous limestone. The vein carries pyrite, and is said to carry gold. The strike is N. 20° W., the dip 30° SW. The development consists of two shafts, 45 feet deep, with a connecting drift, which were filled with water when visited. The vein carries tetrahedrite, in which the silver is said to be the main value. The wall rock is a crystalline limestone. The gangue mineral is chiefly quartz, and the vein carries a little copper pyrite. Assays are said to have shown values of $600 in silver and $20 in gold. These values are said to continue in depth. The silver seems to decrease in depth, and the gold to increase. The strike is N. 20° E., the dip 30° SE.

*Triangle No. 2 claim.*—This claim lies adjacent to Beauty No. 1 on the north. A quartz vein 4 to 5 feet in width is exposed in a pit, in which the quartz is interbanded with crystalline limestone. The mineralization seems to be confined chiefly to the bands of quartz. The strike of the vein is N. 40° W., the dip 35° NE. The gangue minerals are quartz and calcite, which form a coarsely crystalline intergrowth. Values are reported as high as $40 to the ton.

*Welcome claim.*—This lies adjacent to the Triangle on the north. A small pit has been sunk at a contact of limestone and graphitic schist, where there is a shear zone which has been mineralized. Both the graphitic schist and the limestone are silicified. The vein carries pyrite and is said to carry free gold.

*Fortune claim.*—This property lies near the south end of James Lake. There are three veins; one is well defined and is about 2 feet in width, the others are about 1 foot and about 18 inches in width. They are separated by the country rock, which is a graphitic schist. Smaller veins cut across the larger ones. The gangue is chiefly quartz, and the ore for the most part is tetrahedrite. The vein carries some graphite. The strike is about N. 60° W., the dip 10° NE. About 100 feet away the strike turns abruptly to N. 30° W., with the same dip. The development consists of a small pit.

*Jumbo claim.*—This claim is west of the Welcome. A shaft has been sunk to a depth of 40 feet. The strike is N. 45° E., the dip undetermined. The vein consists of a bluish quartz, fractured and recemented by white quartz, and is 2 to 3 feet thick. The ores are gold and tetrahedrite. The values were not learned. The mine workings show many planes of movement in the country rock, which is graphitic phyllite.

*Matilda claim.*—This lies adjacent to the Fortune on the north. It has a well-defined quartz vein, 3 feet in width, with strike about east and west, dip 60° S. A decomposed mica-schist forms both walls. The quartz carries pyrite and is said to carry gold. The schist is slickensided, and along these slickensided surfaces mineralization has taken place.

*Golden Fleece mine.*—This is one of the most extensively developed mines of the Dolomi region, but unfortunately only a couple of hours could be given to its examination. It is connected with Dolomi by a tram, which was not completed when visited. A prospecting stamp mill has been erected, and the property includes a number of substantial buildings. The country rock includes dolomitic white and blue crystalline limestone, the ore being usually found near the contact of the two. The transition between the two limestones, though rather abrupt, at the same time appears to be one of metamorphism. The limestones are cut by diabase dikes, which cut across the foliation and are unaltered. The earlier developments of this property were made under a misconception of the character and position of the ore body, and much of the money was wasted. The mine workings which are now being used consist of two tunnels and several shafts. The vein apparently cuts the lamination of the limestone. The ore, which occurs in lenses, varies from a few inches to 5 or 6 feet in thickness. These lenses sometimes nearly pinch out, but they are always connected by vein matter. The ore is closely associated with dikes of a diabasic character, which it cuts. The strike of the ore bodies varies from north and south to N. 45° E.; and the dip, as a rule, is low, varying from 10° to 45°. The ore body is usually well defined. The hanging wall is most often a blue crystalline limestone, and the foot wall a white crystalline limestone. Near the contact with the vein the hanging wall is broken and brecciated and the mineral-bearing solutions have penetrated it, as they have also some of the diabase dikes.

In the development of the mine use has been made of the limestone caverns, which the ore bodies seem to follow, in a rough way. This suggests that the ore was deposited along channels of solution and may be a replacement. Unfortunately the limited time spent at this mine did not permit of solving the interesting problems connected with the occurrence of the ore. As far as could be determined, the mine workings show that there are two distinct veins, separated by a considerable thickness of limestone. These veins are roughly parallel, bend in their strikes, and have low dips. Their outcrops form a curved line, and their general form is probably that of a broad basin. The northern rim of the basin has not been found, so that it is quite likely that the dip becomes steep underground beyond the present mine works. The veins are formed of a series of lenticular ore bodies, which are connected by narrow necks.

The ore is free gold, tetrahedrite, and pyrite. That which was being mined when visited is said to have yielded, with some sorting, $40 to $60 at the mill. Two specimens were collected by the writer, which were not commercial samples, but

were taken more or less at random. These were assayed by Dr. E. T. Allen in the Geological Survey laboratory. The one from the leanest ore yielded 2.36 ounces in silver and 0.05 ounce in gold. The other was from the highest class of ores, and yielded 9.96 ounces of silver and 4.17 ounces in gold.

*Copper Lake group.*—This is a group of claims lying east of the Golden Fleece, on which but little development work has been done. On one claim a zone of mineralized quartz was seen, 5 or 6 feet in width, carrying copper-bearing minerals. The vein occurs in limestone which is much sheared and slickensided. The vein shows brecciation, similar to that of the Golden Fleece vein, and resembles the Golden Fleece in character. The ore is iron and copper pyrite and tetrahedrite, with probably some free gold.

*Beulah claim.*—This lies to the south of and in part overlaps the Golden Fleece, and was in litigation at the time of our visit. A small cut exposes a mineralized zone 5 or 6 feet in width. The zone is made up chiefly of vein quartz, including some of the mica-schist which forms the foot and hanging walls.

*Welfleet claim.*—This claim lies to the west of the Jumbo. It consists of a very large quartz ledge, 20 to 25 feet wide, carrying graphite and occurring in graphitic schists. It carries pyrite, and its gold values are said to run from $2 to $4. What is said to be the western extension of this has been staked under the name "Sarah claim."

*Home claim.*—This lies north of the Welcome. It is a quartz vein, 12 to 18 inches thick, cutting coarse limestone beds. The limestones are faulted and slickensided. The strike is N. 60° W., dip questionable. The development consists of a pit about 8 feet deep. At the surface the vein has a width of 2 feet, but it narrows down to 18 inches near the bottom of the pit. It carries pyrites and tetrahedrite.

*Alpha claim.*—This lies near the coast, northeast of the Home claim. The strike is N. 20° E., dip 80° NW. It is an 18- to 24-inch quartz vein in white crystalline limestone, apparently somewhat mineralized. No development work has yet been done. White crystalline limestone forms both walls. The vein cuts across the stratification of the limestone.

A small cut has been made on what appears to be the same vein, 200 feet from the above outcrop. At this point a 3-foot vein is exposed, with strike N. 40° W. Both walls are crystalline limestone. Ore is chiefly vein pyrite. According to the owner, assays show values running from $4 to $25 in gold.

*House claim.*—This claim is located a mile north of Dolomi, near Paul Lake. It is a quartz vein, 12 to 24 inches thick, carrying iron pyrite, copper pyrite, and gray copper ore, exposed in a small pit. The vein has been faulted, the throw being about 12 inches. The strike is N. 15° E., the dip 30° NW. The wall rock is a white crystalline limestone.

*Pauline claim.*—This claim is about 1½ miles from Dolomi and a quarter of a mile north of Paul Lake. The developments consist of a pit 10 feet deep and a cross-

cut 6 or 8 feet wide. The ore body is a small fissure vein which cuts banded blue and white crystalline limestone. The vein in the pit has a width of 4 to 6 inches and strikes N. 50° W. The limestone has the same strike and dips 20°, while the vein dips 80° to the south. The vein cuts the bed rock at about right angles. The limestone shows banding and faulting parallel to the vein. In the cut a mineralized zone 6 to 8 feet wide is exposed. In this mineralized zone are numerous quartz stringers and also mineralized country rock. The quartz is sheared and banded. The strike is about N. 60° W., the dip 45° NE. At a third locality on this vein there is a crosscut tunnel about 40 feet long, which intersects the vein at right angles to its strike. The hanging wall is well defined, while the foot wall was buried under débris, but the width of the vein is probably 3 feet. Some mica-schist occurs within the vein. The ore is similar to that described.

*Valparaiso mine.*—This mine lies to the northeast of Paul Lake, about 2 miles from Dolomi. It has been extensively developed and some gold ore has been shipped from it. There are two shafts, about 100 feet apart and about 40 to 60 feet deep. At the westernmost shaft the dip of the vein is about 34° N., the strike being N. 60° W. The hanging wall is slickensided and is separated from the vein by a thin seam of gouge. The hanging wall seems to be well defined, but the foot wall carries some ore. The distance between the walls at the bottom of the westernmost shaft is about 6 feet. Only a part of this, however, carries values. Brecciation has taken place along the foot wall, with more or less recementing. Like the Golden Fleece, this vein, in a general way, follows a series of cavities. The vein carries tetrahedrite, galena, pyrite, and sometimes zinc blende, besides the free gold. The vein matter in the western shaft, according to the superintendent, is blocked out by seams which are lines of movement. The mineralization seems to follow a line of brecciation, and it is along this line of brecciation that the solution of the limestone has taken place and cavities have been formed.

In the easternmost shaft the dip is 35° to the north. The hanging wall is well defined. The mining operations are in a mineralized zone 5½ to 6 feet in width, from which ore was being shipped at the time of our visit. The vein at the surface shows a maximum width of 12 feet, with limestone forming both the hanging and the foot walls. Values as high as $70 and $80 a ton are reported from the picked ores of this mine. Since it was examined one shipment of ore is said to have yielded $185 per ton.

*Wednesday claim.*—This is located on the south side of Paul Lake, northwest of Dolomi. A small cut has been made, which exposes a vein 3 feet wide at the surface. The country rock is a micaceous calcareous schist, which is much faulted, the mineralization seeming to be along the fault planes. The gangue mineral is chiefly calcite. The strike is N. 50° E., the dip 45° to 60° S. A tunnel has been driven about 20 feet. The country rock is white crystalline limestone containing bands of mica-schist.

*Jessie claim.*—This is located on the north shore of Paul Lake, adjacent to and

east of the Valparaiso. The strike is about N. 60° W. and the dip 20° N. The vein proper is about 1½ feet in thickness; above this occurs about 1½ feet of silicified limestone and quartz, above which the hanging wall is composed of limestone. The foot wall is a chloritic schist. The vein minerals are chiefly iron and copper pyrite with free gold.

*Paul claim.*—This lies adjacent to the Jessie on the east, and is an extension of the same vein. The strike is N. 60° W., the dip 10° N. The vein is partly under the lake, and seems to have a thickness of about 3 feet. White limestone probably occurs below as well as above the vein. The vein, which is well defined, carries free gold and pyrite. Along the contact of the vein and hanging wall the limestone is brecciated and recemented by quartz. This is the place where gold was first discovered in the Dolomi region. The discovery was made by Paul Johnson, an Indian boy, who first found the bright particles of gold on the shore of the lake.

### KITKUN BAY.

*General description.*—Kitkun Bay is an almost landlocked body of water, which has not been charted, and is connected with Brennan Bay, a southerly arm of the western part of Cholmondeley Sound, by a narrow neck of water. The accompanying maps (Pl. II and fig. 5) are based on a rough traverse made during the course of the work. The entrance to the bay is by an inlet not over 50 yards wide, which, except at high and low water, has a very strong current. The deepest water is on the east side of the channel, which is apparently free of rocks. The west side of the channel has many rocks in it, some of which are exposed at low tide. No soundings were made, but there is probably considerable depth of water even at low tide.

The shores of the bay are low and the topography is a rolling upland. The mountains near the bay do not reach altitudes of more than 1,200 feet. A broad, flat depression connects it with Mineral Lake to the south.

The geology of the ore deposits of the Kitkun Bay region is very similar to that of the region adjacent to Dolomi, the former being, in point of fact, a northwesterly extension of the latter.

The bed rock of the region is a crystalline limestone, with some phyllites, and belongs to the Wales series. It has a general northerly-southerly strike, with many variations in dip. Associated with these limestones are many bands of chloritic schist, which are often highly contorted. The relation of the schist to the limestone shows that the schist is an altered intrusive. The schist sends tongues into the limestone and includes fragments of the limestone. Since this intrusion the series has been intensely folded, and while the broad structures run nearly north and south, the minor folds stand at all angles.

The ore bodies contain free-milling gold ores. They consist of true fissure veins, which often carry high values, and of mineralized zones in greenstone-schists,

which are usually larger, but do not have so large a gold content. Small blebs of quartz and calcite are common in the schist, and these often contain pyrite. In the region adjacent to Brennan Bay many of these quartz veins have been staked, but, so far as the writer knows, no developments have been made. On Kitkun Bay some work has been done at three or four localities.

*Tomboy claims.*—This group lies about a mile east of Kitkun Bay and about 300 feet above tide water. A series of quartz ledges, which the owner claims to have traced about 3,000 feet, strikes N. 30° W., and forms conspicuous knolls. The walls of the vein are not always determinable, but where exposed the vein has a minimum thickness of 20 feet. Much of it is a barren-looking quartz, somewhat stained with iron. Where exposed in a small stream which cuts across the vein it contains granular pyrite. At this locality the wall rock was determined to be white limestone on the west and chloritic schist on the east, with a dip of 70° to 80° S. Both walls of the vein seem to be more or less mineralized. If it carries any values they are probably concentrated near one of the walls.

*Maggie May claim.*—This property is located about one-fifth mile from the beach, nearly due east from the central part of Kitkun Bay, 275 feet above tide water. The vein is of vitreous quartz and carries granular pyrite. The strike is N. 30° E., dip 75° NW. The foot wall is crystalline limestone, and chloritic schist forms the hanging wall. Near the contact with the hanging wall the quartz has permeated the country rock. The contact with the foot wall is not exposed. One assay, it is said, gave $4.80 to the ton. No developments have been made, except a small open cut.

*Fawn claim.*—This is located about half a mile east of the Maggie May and 750 feet above tide water. Six feet of mineralized quartz are exposed, cutting chloritic schist. The vein stands about perpendicular and strikes N. 40° E. It sends one offshoot 18 inches in width into the wall rock, and the country rock near the ledge is permeated with small veins. The best-looking ore is about 2 feet wide, near the west wall. The minerals are pyrite and galena. An assay of what was probably a picked sample is said to have given $26 in gold. This vein is said to have been traced through three claims and to widen out locally to 14 feet.

One hundred feet to the east of this is a second vein on the same claim, which is said to have been traced for 1,500 feet. A width of 4 to 5 feet is exposed in a cut. It is similar to the first vein, but does not seem to be so heavily mineralized. It carries fragments of the wall rock, which is a chloritic schist.

*Crœsus group.*—This group embraces a number of claims near the southern end of Kitkun Bay. Of these the San Juan, 900 feet above tide, shows a vein of quartz 3 to 4 feet thick, striking east and west and dipping 20° N., both walls of which are formed of chloritic schist. The quartz vein itself, according to Mr. Eugene A. Knapp, superintendent of the property, does not carry gold, but a mineralized zone about 4 feet thick, lying under the quartz vein and consisting of schist and

quartz veins and stringers, carries values. The gold contents have not been determined, but the ore is of low grade, the values probably running from $8 to $10. The larger vein of quartz is barren, and the mineralizing solutions seem to have come in after it was formed. Mr. Knapp states that the gold is always accompanied by manganese. A short distance to the northeast of this vein limestone is exposed. The schists in which it occurs are mineralized, folded, and probably much faulted The zone of mineralization, according to Mr. Knapp, seems to follow a small anticline of schist which underlies the limestone.

The Cresus claim proper lies about one-half mile to the northeast of the San Juan, and is about 1,100 feet above tide. A fissure which has been filled by mineral-bearing solutions cuts chloritic schists and limestones. The pay streak varies in thickness from 4 to 8 inches. According to Mr. Knapp, there has been faulting along the fissure, with a downthrow toward the hanging wall. Gold occurs associated with a black mineral, probably manganese, and with iron minerals. The ore carries some metallic copper. The fissure cuts across both schist and white crystalline limestone, and in places follows the contact between the two. It seems to be richest where it is in contact with the schist. The limestone near the vein is somewhat silicified. The developments consist of a small shaft and two tunnels.

Some interesting exposures occur a quarter of a mile to the west, where a schist, heavily charged with magnetite, is exposed. These magnetite-schists are apparently a part of the greenstone-schist series. The magnetite seems to be secondary after sulphides of iron. Near at hand is an open cut, in which the highly crystalline limestone carries many metamorphic minerals. Among others, hematite, epidote, and chalcopyrite were noted.

### SOUTH ARM OF CHOLMONDELEY SOUND.

*General description.*— The South Arm of Cholmondeley Sound has a length of about 8 miles and averages less than a mile in width (see Pl. II). Its head is said to be connected, by a portage of not more than 6 miles, with the upper end of Klukas Inlet, on the west side of Prince of Wales Island. The land rises abruptly from the water, and the mountains, which trend parallel to the inlet, reach altitudes of 3,000 feet.

The bed rock in this region is crystalline limestone, striking about north and south. With it there are associated schistose greenstones and some massive intrusives. The former are quartz sericite-schists, which contain considerable chlorite, and belong to the Wales series. The massive rock occurs in the form of dikes cutting across the foliation of the sedimentary beds. Specimens from two of these dikes were studied under the microscope; one proved to be an olivine-diabase, and the other is probably an altered andesite.

The ore bodies are of two types: Mineralized zones in quartz-sericite-schist, carrying copper and gold values; and veins in white crystalline limestone affording ores of silver, lead, and zinc.

*Friendship group.*—This group lies on the west side of the South Arm of Cholmondeley Sound, 2½ miles from the entrance. The developments which have been made are close to the shore, and include a small cut and a shaft about 15 feet deep. The mineralization has taken place along a contact of greenstone-schists and white crystalline limestone, and the mineralizing solutions have penetrated both walls. The contact between the schist and limestone is apparently a line of movement, as the rocks show evidence of faulting. The greenstone-schist seems to be intrusive, though this could not be definitely determined. At one end of the claim a small cut shows a vein about 2 feet in width. Six hundred feet to the north, in a small shaft, a vein, which is probably the same, is exposed and shown to have a thickness of from 3 to 3½ feet. The ore is distributed in bunches and layers and is not evenly disseminated. The gangue minerals are coarse crystalline calcite and white quartz. Samples of ore are said to have run as high as 26 per cent in copper, with a gold content of $1. The ore is chalcopyrite and bornite.

*Ketchikan Copper Company.*—This company owns a group of 12 adjacent claims, which lie on the west side of the arm and join the Friendship group on the south. When visited there was unfortunately no representative of the company on the property. Since then the writer is informed that development work is being pushed vigorously.

The ore body, as far as determined, is a mineralized zone, which occurs in a quartz-sericite-schist. This schist is made up essentially of bluish quartz and sericite, and it is often banded. Chlorite is a very common accessory mineral. While it has many of the characteristics of an altered sediment, yet it strongly resembles the schists found in association with the ores at Niblack Anchorage, which are believed to be altered rhyolites. It seems likely that more detailed studies will show that this schist has been intruded into the sedimentary series as a massive rock and subsequently rendered schistose by crustal movements. During this deformation, or possibly in part subsequent to it, the ore-bearing solutions were injected. The strike of this schist belt is about north and south, parallel to the inlet, while its dip is variable. Its boundaries were not determined, but the belt must be several hundred feet wide. Nearly all of the schist belt contains more or less pyrite, but the commercial values seem to be confined to certain zones, where the movement has been most intense.

About a mile from the beach and 900 feet above tide water a tunnel has been driven for about 300 feet. The tunnel is intended to cross the ore bodies, but, as these vary considerably in their trend, the tunnel in part runs parallel to the ore. A number of mineralized zones, which carry iron and copper pyrite, are exposed in the tunnel. Owing to the changing courses of these veins it is impossible to estimate their thickness from a cursory examination, but it must be considerable. The mineralized zone is impregnated by pyritic minerals, which occur in small veins.

In a small gulch lying southwest of the tunnel, at an altitude of 950 feet, a

mineralized zone was seen, occurring in a soft chloritic schist striking N. 40° W. and dipping 75° N. The siliceous mineralized rock is of a dark hue and is heavily charged with pyrite. This zone was observed at several localities, and found in each case to carry copper and iron pyrite and copper oxides. The larger veins are cut by smaller ones, which are also ore bearing. The dikes which cut the schistose series have already been described. They are of economic interest, because near their margins the mineralization of the schists is usually more intense. The mineralization of the schists has taken place since the intrusion of the dikes. The owners report the ore body exposed in the tunnel to carry values of copper, gold, silver, and lead of from $2.50 to $25. They estimate the average of the ore bodies exposed to be $4 to $5. The fact that the ore body is large, and is in a position to be cheaply mined, will probably make it possible to handle even ores of the lower grades, especially since they are well adapted for concentration.

*Silver-lead prospects.*—These are said to be located on the west side of the arm, 2 miles from the beach and 2,000 feet above tide water. The trail leading to them could not be found, so the locality was not visited. The veins are said to occur in a white crystalline limestone, and to be chiefly galena bearing. Mr. Eugene A. Knapp, who has opened up one of the properties, reports an ore body 12 feet in width.

#### WEST ARM OF CHOLMONDELEY SOUND.

*General description.*—No discoveries of importance have been made in this region (see Pl. II), though, as in other parts of the district, a great many claims have been staked, but no attempt has been made at their development. The country rock of the region is chiefly a greenstone-schist, with bands of crystalline limestone and phyllites into which the greenstone was intruded. These rocks belong to the Wales series. In some cases mineralized quartz veins and blebs have been found in the greenstone-schist, but none of these have thus far been exploited.

At the west end of the arm, near the beginning of the trail to Hetta Inlet, a number of claims have been staked. One of these, entitled Earl No. 1, is about half a mile from the beach. The country rock is a quartzitic schist, associated with graphitic phyllite, and in it are some disseminated quartz blebs which carry iron pyrite.

About a mile north of Sunny Point, near the entrance of the arm, some prospecting has been done, and a claim, usually known as the Anderson property, is said to carry copper values. We were unable to visit this claim, but it seems very likely that it is a southern extension of the copper-bearing rocks of Skowl Arm.

#### TWELVEMILE ARM.

*General description.*—Twelvemile Arm is a narrow inlet which makes off in a southwesterly direction from Kasaan Bay. (See Pl. II and fig. 6.) At the head of the bay is a broad flat—the delta at the mouth of a stream of considerable size. At other points the mountains rise abruptly from the water.

The bed rock lying immediately adjacent to Twelvemile Arm is chiefly crystalline limestone, with considerable intrusive greenstone, both massive and schistose. The massive greenstone is of a dioritic character. The schistose phase is chiefly chlorite and actinolite-schist.

West of the limestone belt there are black graphitic schists, with which greenstones are likewise associated. The beds have a general northwest-southeast strike, with variable dips. The phyllites seem to underlie the limestone, and together they have been thrown into open folds. These beds belong to the Wales series, which is usually more closely folded.

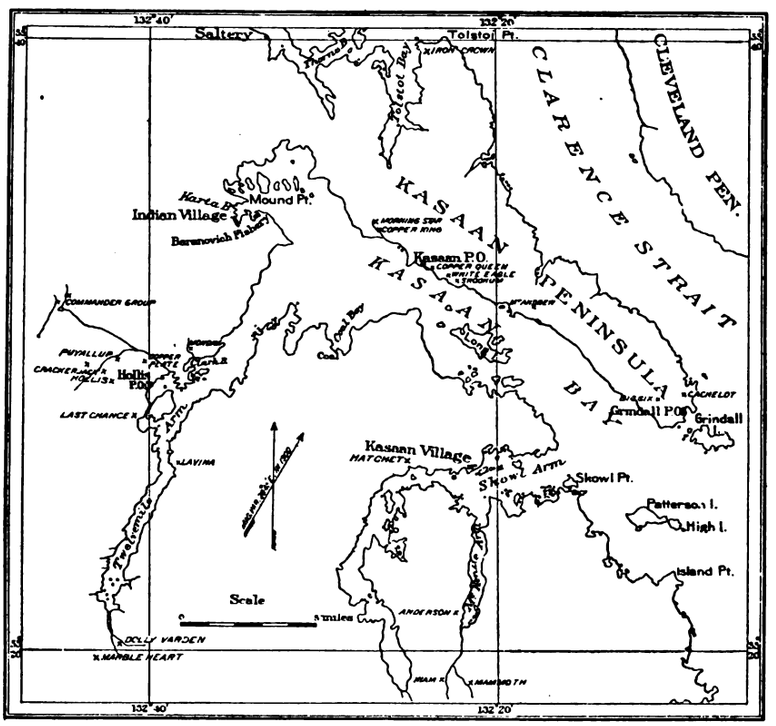


FIG. 6.—Sketch map of Kasaan Peninsula, Twelvemile Arm, and Skowl Arm, showing claim locations.

Dikes of a bluish-gray porphyritic rock were found in the phyllites at several localities. This rock, with which some of the ore bodies were found to be closely associated, is too much altered to admit of a definite determination, though it resembles the dike rock of the Thorne Arm region, which was also indeterminable. At one locality some rhyolitic rocks were observed, but their relation to the bedded series was not determined. The ores of the region yield gold (in part free milling), lead, and a little copper. The ore bodies occur in true fissure veins, which cut the country rock at various angles. One set of veins is found in the phyllites, another occurs along shear zones in the diorite. The veins in the phyllites are closely

vein 2 to 2½ feet thick, with wall rock of slate, and similar in character to the Crackerjack vein. The vein strikes in a northwest-southeast direction and dips about 20° N. It seems to follow a true fissure, and is said to have been traced a mile to the west. One hundred yards to the east the vein has a thickness of 4 or 5 feet. At this point a gray porphyry dike splits the vein. The dike itself is mineralized and carries gold values. Assay returns give $6 to the ton in gold. At the first locality described assays have shown values as high as $100 to the ton.

*Last Chance claim.*—This is believed to be located on an extension of the Hollis vein, and lies about a mile southwest of the town of Hollis. The developments consist of a small cut, exposing a vein 3 to 5 feet in thickness, in a country rock made up of curly slate. Greenish porphyry is associated with the vein. The vein is said to have been traced through the Keokuk claim to the Hollis. About 50 feet below the principal opening on this same claim there is a smaller vein, 12 to 18 inches in thickness, cutting a porphyry dike.

*Commander group.*—This group of claims lies about 7 miles to the northwest of Hollis. At the time of our visit the only communication was by a rather primitive trail.

The Flora claim of this group has been developed by a tunnel about 50 feet in length, following a vein which strikes about east and west. The vein follows a zone of shearing which is from 1 foot to 18 inches in width. Small calcite veins are found in this zone of fracture, and some of these follow joints which run at right angles to the plane of shearing. The rock in this shear plane is mineralized. At the entrance to the tunnel the zone is 2½ feet in width, and in its greatest width it is probably not more than 3 feet, and it gradually pinches down and runs into one of the fault zones noted above. The vein matter is well banded and the vein seems to follow a true fissure. Both walls are more or less mineralized. The country rock is a diorite-porphyry, which is in places very much sheared. At this locality the foot wall is formed of a sheared porphyry, while the hanging wall is composed of more massive rock.

Adjacent to the Flora is the Nellie claim, which has been opened by means of a 30-foot tunnel. This is an extension of the Flora vein. The foot wall is formed of sheared porphyry, and the hanging wall of a more massive variety of the same rock. The vein follows a line of movement along the contact of schistose and massive porphyritic diorite. The vein itself, however, is chiefly in the more massive rock, which is brecciated. At the entrance to the tunnel it has a width of about 2 feet, and at the breast of the tunnel 3 to 4 inches. The foot wall is slickensided and striated.

Fifty feet below this vein a small one is exposed in a stream bed, which, however, has not been developed. It follows a brecciated porphyry dike, and consists of a number of quartz stringers. The zone of mineralization is probably 3 feet in width and contains 3 quartz veins. The ore in all these veins is iron and copper pyrite and galena, with quartz gangue. It is currently reported that the averages

show values of $20 to $40 in gold. The writer was informed that the average from one lot of assays yielded $50, chiefly in gold values.

*Monday claim.*—This is located about three-fourths of a mile north of Clark Bay, a small embayment lying immediately north of Hollis. The country rock is a black slate, striking about northwest and southeast. The developments consist of two small cuts, about 100 feet apart and 650 feet above tide. In the first cut the vein shows a thickness of 4 to 12 inches in black slate. In the second the vein is found to follow the contact of a black slate and an andesite dike, along which there has been considerable shearing. The rocks have been sheared for about 3 feet, parallel to the foliation of the slate and to the vein. The vein itself is 12 to 14 inches thick, with some smaller offshoots within the fault zone, within which the slate is reduced to a fine carbonaceous mass and the andesite dike to a clay. A vein of vesuvianite is found in this mineralized zone, apparently introduced at a later date than the ore-bearing vein. The ore is galena and pyrite, and the gangue is made up of quartz and vesuvianite. Values were not definitely learned, but are reported to run from $5 to $8 in gold and 15 to 40 ounces in silver.

*Lavina claim.*—This is located on the east side of Twelvemile Arm, about 2 miles south of Hollis and a quarter of a mile from the beach. A 30-foot tunnel and a cut, located about 900 feet above tide water, reveal an ore body about 6 feet wide, contained in a brecciated zone in a rock which is probably rhyolite. The strike of the vein is nearly east and west and the dip 65° N. Considerable country rock is included within this brecciated zone, which has been permeated by small quartz veins. The ore is chiefly iron pyrite, with some copper pyrite. Its gold contents were not determined.

*Marble Heart claim.*—This lies about 2 miles to the southwest of the southern end of Twelvemile Arm. The country rock is a crystalline and semicrystalline gray and white limestone, with some argillaceous layers. The developments consist of a shaft, probably 20 feet deep but filled with water at the time of our visit, and a small tunnel about 25 feet below. The tunnel followed a small vein of galena. The exposures in the tunnel showed the limestone to have been intensely squeezed and metamorphosed.

*Dolly Varden claim.*—This is located about 1½ miles southeast of the head of Twelvemile Arm. We were unable to visit this claim, but learned that the country rock is a white limestone, and that the ore is copper pyrite and malachite, carrying some gold values. It is also reported that other veins in this vicinity have been developed. One carrying copper and gold is reported on an unnamed inlet which connects through to the west side of the island, about 6 miles to the southwest of Twelvemile Arm.

### KARTA BAY.

*General description.*—During the summer of 1901 important discoveries were reported from a region lying 8 or 10 miles southwest of Karta Bay (see

Pl. II and fig. 6), which we were, unfortunately, not able to visit. Karta Bay is a western arm of Kasaan Bay. The best evidence available suggests that this is an extension of the mineral belt lying in the Hollis region of Twelvemile Arm. Mr. Samuel Lichtenstadter, who is exploiting a property which is part of the Constitution group of claims about 10 miles from the coast, reports that the vein is well defined in country rock of slate, and is from 2½ to 3 feet wide, with an inch or two of gouge next to both walls. He reports that by using a lake he was enabled to obtain about 5 miles of water transportation. The values are both free and combined gold, reported to run from $4 to $200. Some galena deposits have also been reported from this region.

SKOWL ARM.

*General description.*—Skowl Arm (see Pl. II and fig. 6) is a western branch of Kasaan Bay. A high land mass divides its upper part into the Western Arm and what is usually known as McKenzie Arm. The shores are abrupt and the mountains reach 2,000 feet or more. Both channels are studded with small, rocky islands, and navigation is rendered dangerous by the fact that there are a number of uncharted rocks.

The country rock of the region is for the most part igneous, except along a few miles of the northern shore, where phyllites and limestones of the Wales series outcrop. It is probable that a more careful search would reveal other areas of these sediments. The igneous rocks offer considerable variety in composition, but they are here all grouped together as the Kasaan greenstone. Among the more massive rocks of this group diorite-porphyry or andesite predominates. The schistose greenstones are chiefly epidote-, actinolite-, or chlorite-schists. These schistose phases seem to be altered phases of the massive rocks and to be confined to certain zones of shearing.

The ore bodies are chiefly copper and nickel deposits, which often carry gold values. These occur in bunches and in irregular shoots in the massive rocks, also along zones of shearing in the schistose phases. The first are irregular in their occurrence, and even the second are in no way comparable to veins. The ores are chiefly chalcopyrite and pyrrhotite, associated with magnetite and iron pyrite. The gangue is the country rock itself, epidote, calcite, and some quartz.

In the Skowl Arm region only one claim was visited in which the country rock was sedimentary. The vein in this case was inclosed in graphitic phyllite.

The developments thus far have been confined almost entirely to the McKenzie branch of Skowl Arm. Claims have been staked elsewhere, but have had little or no work done on them.

*Kiam group.* This group is located about 4 miles south of McKenzie Arm, with which it is connected by a trail. The mine workings, at an altitude of about 2,200 feet, consist of a crosscut tunnel, about 300 feet long at the time of our visit, which has since been extended 100 feet farther, but had not at last reports reached the ore

body. Near the crest of the mountain a body of chalcopyrite and pyrrhotite is exposed at the surface. The trend of the outcrop is about east and west, and the vein has a width of about 20 feet. In this width of 20 feet are included some masses of the country rock, which is an altered diorite-porphyry or andesitic rock. The walls of the deposit are ill defined, there being more or less gradation. Below the top of the mountain, at an altitude of about 2,250 feet, a tunnel has been driven across the vein at a depth of about 50 feet, and exposes ore for nearly its entire length. The ore is copper pyrite with some pyrrhotite. The latter is said to carry nickel. The country rock is nearly massive, but shows some foliation. The strike is N. 60° W. The assays reported by the owners show copper values from 5 to 30 per cent and nickel values of $35 per ton. The ore contains some sphalerite (zinc blende) and iron pyrite and a little gold.

The surface showing of this property is excellent, it being as fine a body of pyrite ore as has been found in the region. The fact that there are shear zones in the greenstones makes it probable that the mineralization will extend in depth, in spite of the fact that the ore body is not a well-defined vein.

*Red Rose, Hecla, and Bertha claims.*—These were not examined by the writer, but are said to lie about three-fourths of a mile southwest of the Kiam. The deposits are described as consisting of three parallel veins, aggregating 50 feet of ore, which is chalcopyrite and pyrrhotite. The occurrence and ore are said to be in every way similar to those of the Kiam deposit.

*Mammoth and Lake View claims.*—This group is about a mile southeast of the Kiam group, 1,000 feet above tide water and 2 miles from the beach. The country rock is of dioritic or andesitic nature, but in the vicinity of the ore body has been sheared and changed to an actinolite-schist. At the outcropping of the vein, where some stripping has been done, an ore body with a width of 8 to 10 feet is exposed. Near at hand another exposure shows the mineralized zone to have a width of 20 feet. The ore, which is chiefly chalcopyrite and some pyrrhotite, occurs in solid masses separated by angular horses of greenstone, more or less schistose. These horses, which are lenticular in outline, occur in various parts of the ore body. The general strike of the ore body is about east and west, and the dip is about vertical.

A crosscut tunnel has been driven, which intersects the ore at a depth of 20 feet, exposing it for 6 to 8 feet, and passing through it into a mass of schistose greenstone, which seems to be a horse, since there is ore beyond it. So far as could be determined, the crosscut, which has been driven about 8 or 10 feet beyond this horse, had not reached a well-defined ore body, though all the rock contains considerable chalcopyrite. The crosscut is 50 to 75 feet below the surface outcropping, which shows ore for a breadth of 8 to 10 feet. The owner states that ore had been found at four different places along a width of 400 feet, and claims to have traced the vein through five claims. It is claimed that the Anderson property, which lies near Cholmondeley Sound, is on the extension of this vein.

The ore is chiefly chalcopyrite, with some pyrrhotite and iron pyrite, and some pyritiferous vein quartz in small blebs. There can not properly be said to be much gangue, though there is some calcite and epidote. In parts of the deposit the ore is disseminated through the wall rocks. The wall is usually not very well defined, though sometimes marked by a shear zone. From samples taken near the surface the owners report values as follows: 19½ per cent copper, 3 ounces silver, $4.80 in gold, and traces of nickel. The presence of so much silver suggests that galena may be present, though none was observed by the writer. A qualitative examination of a specimen of the ore showed the presence of zinc blende.

*Anderson's claim.*[a]—This claim lies 100 yards west of the lower end of Mackenzie Arm. A tunnel in chloritic schist shows a zone about 3 feet in width carrying copper pyrite. The strike is about east and west, and the dip about 90°. The country rock, which is a chloritic schist, bears evidence of having been much sheared.

*Hatchet claim.*—This claim is about half a mile north of Skowl Arm and 300 feet above tide. The country rock is a black, carbonaceous, pyritiferous slate, striking N. 60° W. and dipping 50° NE. A small cut exposes a fissure vein, which strikes about N. 60° W. and dips 70° N. At its widest point it has a width of about 4 inches. This vein sends numerous offshoots into the country rock, and the collection of stringers gives a mineralized zone about 4 feet in width. Along the fissure there is evidence of abnormal or reversed faulting. Near the plane of movement the schists are much crumpled. The ore is chiefly iron pyrite. An assay showed gold contents amounting to something less than $1 a ton.

### KASAAN PENINSULA.

*General description.*—This peninsula (see Pl. II and fig. 6) lies between Clarence Strait and Kasaan Bay, and is cut out from the eastern coast of Prince of Wales Island by Kasaan Bay on the south and by Tolstoi Bay and Thorne Bay on the north. A low mountain range forms the backbone of the peninsula, with altitudes ranging from 1,500 to probably 2,000 feet. The southern and western shore line is abrupt and almost unbroken, and has practically no shelter from southeasterly storms which sweep up Kasaan Bay. The northeastern coast of the peninsula also rises abruptly from the water, but is broken by a number of indentations, some of which form small harbors.

The first discovery of copper deposits in the Ketchikan district was made by the Russians near the present location of the Copper Queen mine, on the southern side of the Kasaan Peninsula. They seem to have attached little importance to this discovery of a chalcopyrite ore body, and the exact date of the find is not known, though it probably occurred in the early part of the nineteenth century.

At present mining and prospecting operations are going on at a number of localities in the region. Kasaan is the largest settlement on the peninsula, and includes a post-office, sawmill, store, and hotel, and there is a small native village

[a] This claim must not be confounded with the one located near Cholmondeley Sound.

close by. This town is the distributing point for the region tributary to Kasaan Bay. It is not to be confounded with the old Kasaan Indian village, which is located on the north shore of Skowl Arm. Grindall, situated at the southern point of the peninsula, on a small harbor, includes several buildings, post-office, and one store.

The bed rock of the peninsula is largely a massive green porphyritic rock, which is sometimes of a dioritic and sometimes of an andesitic character. The predominant phase is a rock which in hand specimen shows porphyritic feldspar crystals in a light-green groundmass. The phenocrysts are usually labradorite, but in some cases andesine or oligoclase. The groundmass consists of a crystalline aggregate of plagioclase, hornblende, augite, with usually considerable magnetite and often titanite, together with numerous other accessory minerals. In a more acid variety which approaches rhyolite in composition, orthoclase and quartz occur.

The lack of detailed studies has forced the writer to group all of these rocks together, and they have been termed the Kasaan greenstone. Their geologic relations are not well known. The lithologic structure of the predominant type is that of a rock which has crystallized at or near the surface, but the field relations often suggest intrusive masses. The probability is that when detailed studies have been made the Kasaan greenstones will be found to consist of an intricate complex of many types of igneous rocks, embracing both effusive and extrusive phases. Besides the Kasaan greenstone proper, some dikes of a true diabase were observed. Of especial interest are some belts of white and blue crystalline limestone which occur within the greenstone area and whose age was not determined.

Within the peninsula the Kasaan greenstone is usually quite massive, but has two well-marked systems of joints. In this respect it differs from the Skowl Arm region, where well-marked shear zones, which are traceable for considerable distances, have been found in the greenstone. One system of jointing trends about northwest and southeast, parallel to the longer axis of the peninsula, and the other runs about east and west. In some instances considerable movement has taken place along these joint planes, developing local shear zones. The joints are also lines of weakness along which dikes have been intruded.

The ore deposits of the Kasaan Peninsula are very remarkable, and in many ways extremely puzzling. As the mining operations have been limited to shallow open cuts, and have in no case gone more than 50 feet below the surface, there is but little to guide the investigator besides the surface exposures.

The outcrop of the ore bodies usually shows an irregular mass of copper, iron pyrite, and magnetite, which is sometimes sharply defined, but often grades into the country rock by imperceptible transitions. In some cases joint planes form the boundaries of the deposits, and in this event they have well-defined walls. The various types of the Kasaan greenstone form the wall rocks of the ore deposits, and in the vicinity of the ore contain much epidote, and as a rule are so generally altered that their original mineral constituents can not be determined. The ore bodies vary

in size from small bunches a few inches in diameter to masses which reach 50 feet or more in width. In their distribution these deposits are irregular, but seem to occur sporadically in zones, which, with a general northwest-southeast trend, are in some cases half a mile or more in width.

As far as can be determined by the existing excavations, there seems to be more or less of the same irregularity in the vertical distribution of the ore, as is shown horizontally by the surface outcrops. Bodies of ore have been followed to depths of 20 to 50 feet, and then found to give out completely. Again, in drifting, other ore bodies have been found which did not reach the surface. One important fact is, that, as far as the observations of the writer go, these ore bodies, while apparently pinching out completely, are in fact extended by ore occurring in small bunches in the country rock. In other words, while from a commercial standpoint the ore bodies are isolated, from a scientific point of view they are connected by the ore contents of the country rock; the masses of minable ore are bonanzas occurring in a mineral-bearing zone. This is an important point for the mining interests of this vicinity, because it argues well for the continuation or recurrence of the ore bodies in depth.

In some of the mine workings the percentage of magnetite decreases very rapidly below the surface. In these the place of the magnetite is taken by copper and iron pyrite, showing that the occurrence of the former mineral depends upon the alteration of the sulphide minerals near the surface. In certain of the thin sections examined under the microscope pyrite grains were observed, surrounded by secondary magnetite.

The ores of the region are copper pyrite and some bornite. These occur in solid masses, which often carry very high percentages of copper. They are closely associated with iron pyrite and magnetite. The gangue, as far as there is any, includes amphiboles, epidote, vesuvianite, and considerable calcite, together with chlorite and jasper. Some of these deposits resemble true veins, inasmuch as the chalcopyrite and iron pyrite are contained in a coarsely crystalline calcite gangue. Vein quartz, carrying iron pyrite, is found in some of the ore bodies, though it is not very common.

The ore bodies are of two types. In the one, solid masses of chalcopyrite and pyrite are associated with epidotized country rock; in the other, the chalcopyrite and pyrite are cemented by a gangue consisting chiefly of calcite, with some quartz and chlorite. Zinc blende occurs sparingly with the copper pyrite. No pyrrhotite was observed, though it seemed as if it ought to be present, because of the analogy of these deposits to those of Skowl Arm. The ores carry low gold values. It is difficult to give in general terms a fair idea of the values of the ores. It would seem to the writer that there were probably broad blebs of the pyritiferous greenstone which would yield from 1½ to 3 or 4 per cent of copper, with probably several dollars a ton in gold. The ore bodies proper yield from 5 to 30 per cent copper and $2 to $6 in gold.

The origin of these ore bodies offers an interesting field for speculation, but one which it is not worth while to enter with the present meager knowledge of the facts of their occurrence, relations, and distribution. The writer would, however, call attention to their possible analogy with deposits to which an origin by magmatic differentiation has been ascribed.[a] It should be noted, however, that the evidence points toward the conclusion that in the deposits under discussion there has undoubtedly been mineralization subsequent to the cooling of the rock in which they are contained. The quartz and calcite veins can not be explained by magmatic differentiation. The linear arrangement of the ore bodies, together with their parallelism to the planes of movement, leads to the conclusion that they exist in zones of secondary mineralization rather than that they are separations from a cooling magma.

It should be noted that some ore deposits occur at the southeastern end of the peninsula which are quite different from those described above. These seem to be true fissure veins; they occur near the contact of crystalline limestones and intrusive rocks, and carry values in copper and gold.

It would not be advisable to attempt to prophesy as to the future of these deposits. Many who have observed the enormous outcrops of these deposits have been altogether too optimistic as to their value and extent. Others, again, after a very limited amount of prospecting, have become too easily discouraged because the rich ore bodies were not continuous. Much of the money spent has been largely wasted, either because the managers were entirely ignorant of proper mining methods or because they have been over anxious to begin shipping ore before a mine had been developed. The consequence is that on some of the properties the excavations come as near being a mining development as those of a prairie-dog colony. One of the difficulties that has confronted the mine owners is their misapprehension of the real nature of the deposits, which they have regarded as true fissure veins. For this reason their energies have been misdirected in attempts to develop the ore bodies. The deposits are peculiar, and besides plenty of capital they require the management of experienced mining engineers for their exploitation.

*Copper King claims.*—This group is located on the southern shore of the peninsula, near the head of Kasaan Bay, about half a mile from the beach and 100 feet above tide. The developments consist of a shaft about 20 feet deep, a tunnel 30 feet long, and an open cut 35 feet. The country rock is the greenstone of the peninsula, which has already been described. The ore deposit consists of this greenstone, in which disseminated bunches of iron and copper pyrite and magnetite occur, with calcite, epidote, and some quartz as accessories. The limits of the ore body are ill defined, and it passes by gradual transitions into the country rock. Immediately to the south of the shaft there is a very large body of magnetite, whose limits could not be determined. At the crosscut, 100 yards to the west, the following section was exposed: Near the surface 20 feet of greenstone, which is deeply weathered; then 10

[a] For references, see Lehre von den Erzlagerstätten, Richard Beck, Leipzig, 1901, pp. 37–48.

feet of weathered greenstone carrying pyrite; below this 10 feet carrying iron pyrite and magnetite, with some copper pyrite. The gangue of this latter zone is hornblende and calcite. The copper pyrite seems to be closely associated with the calcite. The surface stripping above the crosscut shows a mass of magnetite, copper, and iron pyrite lying in greenstone. The pyrite occurs in irregular blebs and masses, and the whole is cut by small veins of calcite. Twenty-five feet below the open cut is a crosscut tunnel about 30 feet long. In the first 10 feet of this tunnel greenstone is exposed, carrying copper and iron pyrite. With this are many calcite blebs and small calcite veins, the latter following the joint planes. The last 10 or 15 feet exposed in the tunnel are made up chiefly of iron pyrite, with some copper pyrite, the former apparently taking the place of the magnetite, which occurs on the surface in much larger amounts than underground. In the roof of the tunnel there is a greater proportion of magnetite than in the floor. A width of about 6 feet within this mineralized zone is made up of fairly good ore. About 50 feet to the northeast of the tunnel are surface exposures of magnetite, iron pyrite, and copper pyrite, which have been partly altered to carbonates. Assays reported by the owners give 12 to 13 per cent copper and $8 to $10 in gold.

*Morning Star claims.*—The claims making up this group lie to the north of the Copper King. The development at the time of our visit consisted of a shaft 20 feet deep, located about 250 feet above sea level. At the surface a mass of magnetite is exposed, carrying iron and copper pyrite. This iron deposit apparently has a width of 30 or 40 feet. As far as could be determined, the character of the ore body is very similar to that of the Copper King. Considerable coarsely crystalline calcite is found associated with the ore. The ore is said to carry gold values, though exact analyses were not obtained. Five claims are said to be included in this group.

*Copper Queen claims.*—This name is applied to a group of claims lying about a mile east of Kasaan post-office and close to the beach. On the beach there are a number of small shafts, and a quarter of a mile inland about 200 to 300 feet of tunnel have been driven. The country rock in all the workings is a massive greenstone which shows some jointing. Near the beach, and in part below tide water, a number of rich copper pyrite ore bodies have been found. The outline of these deposits is very irregular, though the boundary with the greenstone is fairly clear.

About a quarter of a mile from the beach and 250 feet above the sea a stripping has been made which reveals an irregular body of ore. The boundaries of this ore seem to be formed by the joint planes of the greenstone, which here run nearly north and south and east and west. Taken as a whole, the Copper Queen property probably contains many irregularly distributed ore bodies. The ore pockets, when found, are very rich, and careful prospecting with diamond drill might lead to commercial success.

*Poor Man's claims.*—This property was not visited, and the writer is indebted to Mr. Blaimy Stevens, of Ketchikan, for the following notes. It is located

north of the Copper Queen and about a mile from Kasaan Bay, at an altitude of about 1,200 feet above tide. The developments consist of a 15-foot tunnel with some open cuts. The country rock is similar in character to that of the Copper Queen and other claims in the vicinity. It is cut by a diabasic dike, which forms the foot wall of the ore body. The deposit is a mineralized greenstone mass, carrying copper and gold, with calcite, fluorspar, and quartz. The ore breaks freely next to the dike, but the other wall is not well defined. It has a width of about 15 feet. Throughout this width there are mineralized streaks from 2 to 10 inches thick. The gold values are considerable.

*White Eagle claim.*—This property lies to the east of the Copper Queen, the chief workings being about half a mile distant from it. Considerable money has been spent in constructing a tram, a wharf, ore chutes, buildings, etc. The chief workings are at two localities one-fourth of a mile apart and about half a mile from the beach. The easternmost tunnel, about 50 feet in length, is located 750 feet above the sea. It is connected with the tramway by a chute. The country rock is greenstone, which is jointed, and movement has taken place along the joint planes. Two systems of jointing were observed, one striking N. 45° W. and dipping 80° SE., the other striking N. 45° E. and dipping 75° NE. The ore bodies, consisting of copper pyrite, seem to be limited by joint planes. Within the limits of these ore bodies solid bunches of copper pyrite, separated by gangue, epidote, and vesuvianite, are found. One of these masses, which was said to have been solid ore, had been mined out and an opening 20 by 10 by 10 feet was left. A second tunnel, a quarter of a mile to the west and 550 feet above the sea, was driven for the purpose of cutting an ore body which is exposed on the mountain 75 feet above the tunnel. The deposit is similar in character to that in the eastern tunnel. The ore has been crosscut by a small tunnel which lies in a zone striking N. 50° E. and dipping 45° NW. The jointing strikes northwest and dips 80° SW. At the entrance to the tunnel a diabase dike 8 or 10 feet wide cuts across the country rock. The ore body exposed on the mountain above the tunnel is chiefly magnetite. The sulphide ores from the White Eagle are reported to run 25 to 30 per cent copper.

*Skookum and Elm City claims.*—These claims belong to the same property as the Copper Queen. They are located about a half mile east of the White Eagle, a quarter of a mile from the beach, and 500 feet above the sea. In general character the occurrence is similar to the White Eagle. A tunnel which has been driven a few feet shows that the country rock is dioritic, partly replaced by epidote in the vicinity of the ore body. The ore consists of iron and copper pyrite and is said to carry $10 in gold values. At the face of the tunnel 3 feet of ore, including some country rock, are exposed. Both sides of the ore body seem to be fault planes. The mineralized zone shows evidence of movement. Small veins of calcite are not uncommon.

*Mount Andrew claims.*—This property is located about 2 miles southeast of Kasaan post-office. It embraces about 20 claims, and extends from the beach for half a mile or more inland. The principal developments include a number of open cuts, three shafts, and several tunnels, and are about a half mile from the shore. A corduroy horse trail connects these with a small wharf and several buildings located on the shore.

The country rock belongs with the Kasaan greenstone. At the lowest tunnel, located about 500 feet south of the offices and boarding house and on the Mayflower claim, an ore body in the greenstone consists of massive copper pyrite with much magnetite. The ore occurs in bunches and masses, probably through a width of 50 feet or more. The limits of this ore body are ill defined, but seem to follow joint planes running northeast and southwest. Near the limits of the ore body the country rock is largely altered to epidote. The tunnel at this locality has a length of about 100 feet and is about 1,000 feet above the sea. For a distance of 50 to 100 feet the tunnel was driven through a mineralized greenstone carrying copper pyrite and much magnetite. The inner boundary of this zone is limited by a joint plane, along which there has been movement. Commercial samples are said to run about 2 to 6 per cent in copper and from 30 to 60 per cent in iron. A shaft near the entrance to this tunnel passed through an ore body 13 feet in depth, which ran from 6 to 9 per cent in copper, with several dollars in gold.

The upper workings on the North Star claim include a tunnel about 300 feet in length and a shaft about 60 feet deep connecting it with the surface. Along the tunnel and in several crosscuts the whole rock is more or less ore bearing, and several ore bodies are exposed by crosscuts and winzes. Much epidote and some calcite are associated with the ore. The boundaries of the ore bodies are often joint planes which cut each other at right angles. In many cases, however, the ore body gradually passes into the country rock, which contains irregularly distributed bunches of copper ore. The copper contents of the ores from the tunnel workings are said to run from 1 to 5 per cent. The shaft revealed an ore body 17 feet thick, which carries 4 to 7 per cent in copper and $3 to $5 in gold. Another shaft was sunk in ore to a depth of 42 feet, with 2 to 14 per cent copper.

About a quarter of a mile to the southwest of the shaft is a large exposure of magnetite which, we were informed by the superintendent, had been traced for 1,000 feet. This magnetite occurs in greenstone which is more or less schistose. It is said to contain only 0.02 per cent of phosphorus, but to run high in sulphur. Disseminated through it is considerable copper pyrite, and even when there are no visible copper minerals the magnetite is said to carry about 0.1 per cent copper.

In a crosscut on the Peacock claim of this group there is an occurrence of copper similar to the other ore bodies, which runs 5 per cent copper and $1 to $2 in gold.

The gold values from the lower tunnel are reported to run from $2.50 to $2.75; from the upper tunnel, $3.07 to $3.75; from the Peacock claim, $5 to $6. The aver-

age copper content is said to be from 3½ to 5 per cent. It is interesting to note that a small belt of white limestone is exposed between the upper and the lower tunnel.

It is much to be regretted that our limited time prevented the study of these interesting deposits in greater detail. The ore bodies are larger than any which we visited, and enough excavating has been done to show something of their character. Whatever subsequent developments may show in regard to the richer leads on this property, enough has been done to prove the existence of large bodies of low-grade mineral. As the gangue is very largely magnetite, it ought not to be difficult to find a method of concentration which will give a good shipping ore. In the opinion of the writer the magnetite is, however, a result of chemical action which has taken place near the surface and probably diminishes in depth. It seems not improbable that in these magnetite-bearing deposits a part of the copper has leached out, and the evidence points toward the conclusion that there will be an increase in copper values at greater depths. In this connection it is interesting to note that films of native copper are often found along the joint planes of the magnetite-bearing rock.

*Big Six claims.*—These are located about a mile west of Grindall, in the southern part of the peninsula. The developments consist of a few cuts, which were filled with water at the time of our visit. At the principal cut the strike of the vein is about east and west, the dip 70° S. The ore occurs at the contact of greenstone and a much altered limestone. The mineralization follows the limestone rather than the greenstone. The greenstone forms the foot wall, and this limit is well defined by a fault plane. On the hanging wall the ore grades into the limestone. The ore body is a mineralized zone rather than a vein, but no idea was gained of its dimensions. The greenstones occur on both sides of the limestone belt. The ore is copper pyrite, with native copper occurring in films along joint planes. One hundred feet to the west of this crosscut is a small test pit about 15 feet square. The occurrence is similar in character to the first, consisting of copper and iron pyrite with calcite and quartz gangue. Five hundred feet to the west is another small crosscut which exposes a contact of a ferruginous and a feldspathic rock, all deeply weathered. The contact seems to be a fault plane, which strikes about east and west and dips 80° S. The ferruginous rock is a dark porphyry with iron developed along the seams. Microscopic examination of the feldspathic rock suggests that it is probably an altered pegmatite. The mineralized zone is about 20 feet wide and is said to have been traced for half a mile to the west of the pit.

*Cachelot claim.*—This is located about 1 mile north of Grindall, near Clarence Strait. The development consists of an open cut 10 feet deep. The vein, which is about 12 inches at the surface, widens to 2½ to 3 feet at 10 feet below the surface. The vein seems to be faulted at the bottom of the pit, and is slickensided. The hanging wall strikes east and west and dips 70° N. The vein sends offshoots into both the hanging and the foot wall. The country rock is a diorite, much sheared and jointed. Epidote is developed along these shear zones. A small diabase dike cuts the diorite

and seems to have been intruded previous to the ore. The ore is copper pyrite with quartz gangue, and is said to carry gold values. A specimen taken more or less at random gave 0.41 ounce in silver and 0.14 ounce in gold.

*Tolstoi Bay.*—Tolstoi Bay lies north of Kasaan Bay and marks the northern limit of the Kasaan Peninsula. A number of claims have been staked in its vicinity, but at only one has much development been done. The country rock is of greenstone, similar to that forming the southern part of the peninsula. The ores are copper, probably similar to those which have been described. Tolstoi Bay offers a fair anchorage, but as yet there is no settlement on the bay except a small cabin on the eastern shore.

The Iron Cap is a group of claims lying adjacent to and east of Tolstoi Bay. The country rock is greenstone with some limestone belts. The developments have been chiefly with diamond drill, but we were unable to get the records of these investigations. About a half mile from the beach is an open cut showing a mass of copper pyrite and magnetite scattered through a greenstone. The greenstone is jointed and epidote is developed along the fracture planes. The deposit includes copper pyrite, magnetite, and bornite, with considerable epidote as gangue. It was close to this outcrop that the diamond-drill borings were being made at the time of our visit. A number of similar occurrences of copper-pyrite ore have been found irregularly distributed through this group of claims. The drillings have extended to a depth of several hundred feet, and yet do not seem to have reached below the zone of alteration. A drill core shown the writer consisted of a hard greenstone rock, and carried epidote similar in character to that at the surface, except that it was not porphyritic. As far as could be told from limited exposures, the occurrence is similar to that of the Mount Andrew property. Since our visit it is reported that a shaft has been started.

### HETTA INLET.

*General description.*—Hetta Inlet (see Pl. II) is a deep embayment in the southwestern coast of Prince of Wales Island, which connects with the Pacific Ocean through Cordova Bay. The inlet has not been surveyed, and the accompanying map is simply a sketch and must contain many inaccuracies. The head of the inlet is separated by a 200-foot divide from the West Arm of Cholmondeley Sound. A trail across this divide is a link in the mail route to Coppermount and Sulzer. Freight is delivered by small steamers from Ketchikan, and also by Puget Sound vessels, which occasionally call at the camps along the inlet. The limited time at our disposal did not permit us to make an investigation of the mineral deposits of the west side of Prince of Wales Island. For the sake of comparative study, however, a hurried trip was made to Copper Mountain, and such information about the other deposits was collected as could be obtained from prospectors and other persons.

Like other parts of the coast, the shores are abrupt from the water's edge, and the channels and inlets are deep. The slopes of the mountains are densely timbered

up to an altitude of about 3,000 feet. The higher peaks are somewhat over 3,000 feet in height. The precipitation is probably a little greater than at Ketchikan, and the mean annual temperature is slightly higher. Accessibility, abundant timber, and water powers make the conditions on the west side of Prince of Wales especially favorable for mining enterprises.

The white crystalline limestone of the Wales series, striking nearly north and south, is the predominant country rock of Hetta Inlet. In it are intruded many igneous rocks, some schistose, some massive. The white limestones are closely folded and have great variation in dip. The igneous rocks, so far as determined from the small collection made, include gabbros, diorites, amphibolites, diabases, and pyroxene-syenites. All these are comparatively massive. The greenstone-schists, which occupy considerable areas, are chloritic, and their original character has not been determined.

*Copper Mountain group.*—This property comprises a group of fifteen or twenty claims located north of and adjacent to Copper Harbor, a small eastern arm of Hetta Inlet. The more important of these claims lie along the crest and north slope of a mountain, about 3,300 feet high, whose summit is three-fourths of a mile distant from the north side of the harbor. A gravity cable tramway connects the top of the mountain and the more important workings with the wharf on the north shore of Copper Harbor. Near the wharf are a sawmill and a number of substantial buildings. A part of the excellent water power which is on the property is being utilized for running the sawmill.

The developments have been chiefly made on a claim located at the crest line. Here there is an open cut, about 40 feet deep, which follows a copper vein. About 1,000 feet below there is an old tunnel, which was, however, located without much judgment and failed to reach the ore body. There are a number of small cuts and drifts in the various claims which make up this group.

At the New York claim, on top of the mountain, there is a copper vein varying from a few feet to 30 feet in width. Since our visit this vein has been reached by a tunnel 60 feet below the cut. In this tunnel the ore persists in width, and is made up of copper carbonates, with some nodules of sulphides. The strike of this vein is N. 54° E., and the dip is nearly vertical, probably about 85° E. This vein is said to have been traced nearly to the shore line of the bay by a zone carrying chalcopyrite. The hanging wall is an igneous rock, made up of orthoclase, pyroxene, hornblende, and some plagioclase, and is provisionally classed as an augite-syenite. The foot wall is a white crystalline limestone. The relation of the igneous rock to the limestone seems to be one of intrusion. Near the contact the limestone is considerably altered. The vein is well defined, but sends offshoots into the limestone foot wall, and includes some limestone horses. The ore at this point is for the most part malachite, with some azurite. The gangue is siliceous, with much calcite. The material which was being mined was almost pure ore, with a very little gangue.

The shipments from this open cut are said to have netted $60 to $100 a ton. It is reported that the shipping grades of ores yield 20 per cent and upward of copper and carry considerable values in gold and silver.[a] Much of the ore that was being mined at the time of our visit must run much higher than 20 per cent in copper.

The igneous rock which constitutes the hanging wall at the above-described ore body forms a considerable mass, 600 or 700 feet in width, to the northeast of which is another limestone belt, also metamorphic at the contact, containing a second zone of mineralization. This zone affects a belt of limestone probably 100 or 200 feet in width. Within it the limestones are in places entirely recrystallized and carry copper pyrite and bornite. An open cut on the mountain crest reveals an exposure of ore and country rock about 50 feet in width and 50 feet in depth. This cut is near the boundary of the Indiana and Oregon claims of this group and about 1,000 feet east of the first cut. On the face ore is seen, occurring in irregular bunches in a zone with considerable honeycombed vein quartz. Horses of limestone are plentiful. While the zone is mineralized as a whole, the individual veins seem to cut across the bedding planes of the limestone. The division planes between the horses of limestone and the ore are well defined. The ore is chiefly chalcopyrite and bornite. This zone of mineralization is said to have been traced through four claims to the east.

There is a small cut on the Indiana claim, 200 feet below the crest and on the east slope of the mountain, which seems to be in the extension of the second or northern mineralized zone. As far as could be determined from the limited exposures, this locality is near the contact of the syenite and limestone. The cut shows a metamorphosed limestone which is very siliceous, carrying chalcopyrite and bornite. The gold values in this ore are said to run from $8 to $10.

Close by, on the Oregon claim, a small cut has been made which at the time of our visit was filled in. It is said to have exposed a vein of ore 2 feet in thickness. The dump shows copper pyrite associated with limestone. This ore occurs near the contact of a diabase and crystalline limestone.

The examination of the Copper Mountain region was limited to one day, and the conclusions presented must therefore be regarded as provisional. The country rock is a white crystalline limestone which is cut by an intrusive mass provisionally classed as a pyroxene-syenite, and on both sides of this intrusion mineralization has taken place. The zone on the northeastern side of the intrusive is the wider, but the ore in it seems to be more disseminated. The northwestern zone is better defined and seems to be richer. These deposits must be regarded as contact phenomena. The ores which have been reached in the shallow mine workings are mostly copper carbonates, with some bunches of copper sulphides. The evidence points toward the conclusion that the ore bodies will continue in depth, but how deep the carbonates will go it is impossible to foretell, and it is the belief of

[a] Min. Sci. Press, September 7, 1901, p. 100.

the writer that speculations in this matter are idle. In better developed regions the lower limit of the carbonate ores has been determined by mining operations, but at Copper Mountain no such criteria are available. Many of the mining experts who have visited the Copper Mountain property have been ready to express definite opinions as to these depths, but these gentlemen must have had sources of information which were not open to the writer during his hasty visit. The writer, therefore, while not desiring to prophesy in regard to the depths of the carbonates, would call attention to three important facts. First, the topographic position of the ore body is most favorable for a downward extension of the carbonate ore; second, the humidity of the climate is also favorable for this; third, the presence of considerable sulphide ore near the surface, on the other hand, would seem to indicate that the alteration has not been very complete, and that it may not extend to any great depth.

*Miller Brothers' claim.*—This claim is said to lie north of Copper Bay. It is reported to consist of a large body of rather low-grade copper and gold ore.

*Jumbo claim.*—This claim lies north of Copper Mountain and about 2 miles east from Hetta Inlet, with which it is connected by trail. The occurrence is believed to be an extension of the Copper Mountain ore body, from which it is distant less than half a mile.

*Beaver claim.*—This claim is said to be located a mile from Hetta Inlet, on the north side, near Sulzer. It is said to carry gold and copper values. Sulzer is a post-office and steamboat landing about 3 miles below the head of the inlet.

*Green Monster claim.*—This lies about halfway between Copper Harbor and Cholmondeley Sound. It is connected with Copper City by a trail 5 or 6 miles long. Considerable development is going on, and values are reported to run from $8 to $10 in gold and from 30 to 40 per cent in copper.

### UNUK RIVER.[a]

Unuk River is a stream of considerable size, which rises well back in the Coast Range and flows into Burroughs Bay with a southwesterly course. In the lower 10 miles of its course the Unuk River is said to traverse the belt of granite which makes up the Coast Range. Above the granite the country rock is said to be slates, with a few thin limestone beds and intercalated masses of intrusive granite. The description suggests that these beds belong to the Ketchikan series. The strike of the rocks is northwest and southeast.

Placer gold was reported on the Unuk River during the Cassiar excitement in the early seventies, but it received little attention. It is only during the last few years—since the Ketchikan district has come into prominence—that prospectors again turned their attention to this region. These placers are said to be about 40 miles from the coast, and hence in British Columbia, but probably lie close to the international boundary. The gravels are reported to be very heavy. Rich gold-

[a] It has been thought best to compile the most trustworthy information available about those parts of the Ketchikan district that were not visited by the party.

bearing quartz veins are said to have been found in the vicinity of Sulphur Creek. During the summer of 1901 a company made use of a small stamp mill to test the quartz veins. The tests seem to have been satisfactory, as the same company is now installing a more elaborate mining and milling equipment.

The supplies are taken to the head of Burroughs Bay by steamer, and there transported up the river to Sulphur Creek in scows. There are said to be three canyons on the Unuk River below Sulphur Creek, which are formed by lava flows, through which the river has cut its course.

### BOCA DE QUADRA.

This channel reaches about 30 or 40 miles inland and has many divergent channels. Its upper course must lie largely within the granite belt. Sulphide deposits have been reported from near its mouth, and workable gold placers on one of its confluent channels.

### PORTLAND CANAL.

Portland Canal is a long, deep waterway which runs about 100 miles inland rom the eastern end of Dixon Entrance and marks the international boundary. At its southern end Wales and Pearse islands break it into two divergent channels. Its shores are rocky and abrupt, and the neighboring mountains rise to heights of 2,000 to 7,000 feet.

Almost nothing is known of the geology of the region, but it is probable that much of the canal lies in the granite belt of the Coast Range. A little prospecting has been done, but nothing of importance has been reported on the Alaskan side of the boundary. That the region is ore bearing is shown by the fact that copper deposits (chalcopyrite) have been found on the Canadian side of Portland Canal, on the peninsula which separates it from Observatory Inlet. The country rock in which these pyrite deposits occur is said to be a mica-schist, and they have been described to the writer as impregnated zones. There is a rumor of the occurrence of coal near the head of the canal.

### ANNETTE ISLAND.

Annette Island lies between Duke and Gravina islands. Its length is about 18 miles, extreme width about 10 miles, and area approximately 140 square miles. The island, which is an Indian reservation, is uninhabited except for the Indian settlement of Metlakatla, on the west side. The Indians have a thriving village, including about 500 people, a sawmill, cannery, school, church, and many well-built houses. The story of Metlakatla has been told many times, and need not be repeated here. Everyone in southeastern Alaska owes a debt of gratitude to Mr. William Duncan, who, through his own unaided efforts, has brought these Indians up to a high plane of civilization. He has shown what can be done by teaching the natives to be self-supporting and self-reliant.

The shores of Annette Island are rather low compared with other parts of the

region. Its central part is occupied by mountain peaks, which run to heights of 2,000 and 3,000 feet. The geology of the island was not studied by the writer, but from best accounts it would seem probable that the eastern part is occupied by the rocks of the Ketchikan series. Metamorphic limestones have been found on the island, and also igneous rocks. The first discoveries of ore in the Ketchikan district were made on Annette Island in 1891 or 1892. The deposits are quartz veins carrying free gold, pyrite, and silver-bearing tetrahedite, and are said to resemble those of the Dolomi region, which suggests that the Wales series may be represented. Assays have shown high gold and silver values in some of the ores. There can be no doubt that a part of Annette Island at least lies within an ore-bearing zone.

By act of Congress Annette Island was reserved for the exclusive use of the Metlakatla Indian community. When the act was passed it was supposed that the Indians would become an agricultural people and gradually bring the island under cultivation. This expectation has not been realized, and their occupation of land is confined to 2 or 3 square miles near the village. Under the able guidance of Mr. Duncan they have become an industrial people, owning and operating sawmills and canneries, and engaging in many other occupations, though not in farming or mining. They are prohibited by law from developing mines on the island. The Indians are not required to remain on the island, but leave it and return to it at their own volition. A number have established industrial enterprises in the neighboring region, and have thereby fully proved their ability to hold their own in direct competition with the white man. In fact, the developments of the last few years go to show that their prosperity is dependent on their coming into commercial relations with the white man. Being an industrial community, Metlakatla can not isolate itself from the rest of Alaska. Among its members are many sturdy, self-reliant men, who would be the first to resent the idea that they needed the fostering care of the Federal Government to protect them when they come in touch with the white race.

In view of these facts it would seem only just that a portion of the island, say the region lying tributary to Port Chester, be given to the Metlakatla Indians, and the remainder of the island, which is not now and never will be used by the Indians, be thrown open to mining locations. The Indian side of the controversy which exists between them and the prospectors has been ably presented by others, and the writer has felt impelled to present the side of the prospectors. The latter are represented as a body of adventurers, ready to swarm down on this little community, rob the Indians of their lands, and teach them the vices of modern civilization. In point of fact, many of the prospectors have lived in the region nearly as long as the Indians, who came from British Columbia in the eighties. As a class the prospectors are honest and industrious, and have the greatest sympathy for the good work which has been done at Metlakatla. All that they ask is to be allowed to develop such portions of the island as are not now and never will be used by the Indians.

### DUKE ISLAND.

This is the southernmost of the group of large islands which forms the central part of the Ketchikan district. The position of the island would indicate that the bed rock probably belongs in the Ketchikan series. Little prospecting has been done on the island. Galena deposits are reported, as are also gold- and sulphide-bearing quartz veins. On Marys Island, which lies a short distance to the northeast, copper- and iron-sulphide deposits are reported.

### SOUTHERN END PRINCE OF WALES ISLAND.

To the south Prince of Wales Island narrows down gradually to Cape Chacon, which marks its southernmost point. The coast line is broken by many embayments, and the relief is probably lower than in the central part. The geology is unknown, but the strike of the beds to the north makes it probable that the region is largely occupied by the Wales series.

Some prospecting has been done, but very slight developments have been made. Galena deposits are reported from Cape Chacon, and copper sulphides from Nicholas Bay. Mr. F. C. Schrader showed the writer some specimens of mineralized vein quartz containing pyrite and some galena, which came from the neighborhood of Hunter Bay.

### DALL ISLAND.

Dall Island lies west of Prince of Wales Island. Its coast, which has not been charted in detail, is very irregular. The relief is probably not over 1,000 or 1,500 feet. Limestones and granite are reported to occur on the island. Some prospecting is said to have been done, but no considerable mining developments have been made. The Alaska Industrial Company owns the Mount Vesta group of claims, which are said to be located along a contact of limestone and granite. The ore body is said to be very large and to carry high values in copper, gold, and silver.

## COAL.

In the region visited by us coal has been found at only one locality, and there not in workable quantity. This locality is adjacent to Coal Bay, an indentation of the southern shore of Kasaan Bay. Coal outcrops about a quarter of a mile south of Coal Bay, in a creek bottom. The coal is lignitic, of jet-black color, and finely foliated; it contains resin and some sulphur. The vein as exposed is about 8 inches thick, and the dip is 5 to 10 degrees. The floor is a fine micaceous and argillaceous sandstone through which are scattered small fragments of lignite. A coarser green sandstone 4 to 5 feet thick overlies the coal. The rocks associated with the coal are feldspathic and of such character that the local origin of their materials is suggested. It seems probable, therefore, that this coal was laid down in a local basin with sediments which were derived from the green schists of the neighborhood. No other coal exposures were found in this neighborhood, but the

soft character of the rocks with which the coal is associated makes it unlikely that they would be found except by excavation. It seems improbable that this coal has any commercial value. There are also unverified rumors of the occurrence of coal on Duke Island and on Portland Canal near the international boundary.

### BUILDING STONE AND LIME.

Little attention has been paid to the nonmetallic economic products of the Ketchikan district. These embrace marble, granite, and limestone. Much of the limestone of the Wales series has been altered to a finely crystalline marble, but much of the marble has been so sheared and jointed that it has no value for building purposes. At one locality, at least, it has been found sufficiently massive to quarry and has been developed on a commercial scale. An anonymous writer describes the locality as follows:[a]

"Kosciusco Island, like Dall Island, one of the Prince of Wales Archipelago, is commonly spoken of as if it were part of the principal island. The settlement of Shakan is on Kosciusko Island and not on Prince of Wales Island. At this place there is a large sawmill, a halibut and herring fishery plant, a marble quarry, and a gold-bearing quartz mine equipped with a stamp mill. This locality has not been developed from Ketchikan, but from Wrangell. It has been a port of occasional call for Alaska steamers, and is on a local steamer mail route from Wrangell to fishing stations and Jackson, on the west coast of Prince of Wales Island. The marble quarry is being prepared for exploitation on a considerable scale by a Fargo, N. Dak., company, for which M. Cronin is manager. It is less than half a mile from the steamer landing. A plant of marble-cutting machinery has been put in place. The quality of the rock is claimed to be superior. It is sound, even at the weather exposed surface, and is expected to enter the Pacific coast market in competition with marble brought from Italy in sailing vessels. The gold-quartz vein, owned by Castle & Co., was discovered in 1898. It is a wide vein of low-grade ore, most of the values being carried in pyrite."

It is probable that when the region has been examined in greater detail other areas of the Wales series will be found which contain workable beds of marble.

The granite of the region, as far as known to the writer, has never been examined with reference to its utility as a building stone, and some of it is quite likely to prove of commercial value. A description of the character and distribution of the various granitic types will be found in the discussion of the general geology. The granite of the Coast Range is often considerably sheared, which would make it less favorable for exploitation than the isolated stocks where the rock is more massive. In prospecting for granite it will be desirable to examine those parts of the stocks which are farthest away from a contact with sedimentary beds. Near the contact the granite is liable to contain pyrite, which injures its value for building purposes.

The matter of finding building stones has, in the opinion of the writer, not received adequate attention in southeastern Alaska. The rugged character of the

[a] Min. Sci. Press, September 7, 1901, p. 99.

region and the many waterways are favorable for opening quarries. The glaciation has removed the débris and weathered portions of the rock. The cheap water transportation gives access to an excellent market in the States bordering the Pacific, where building stone is not at all plentiful. The limestones of the region will sometime undoubtedly be exploited for lime, which would supply the local market, and also Puget Sound and other parts of the Pacific coast.

## CLIMATE AND TIMBER.

The conception of Alaska as a region of ice and snow has so strong a hold on the popular mind that it is difficult to remove it. The climate of southeastern Alaska is characterized by mild winters, cool summers, and abundant rainfall. The lowest temperature recorded at Sitka is −3° F., at Juneau −4°.[a] The highest is 80° at Sitka and 88° at Juneau, and these extremes are very exceptional. The precipitation in southeastern Alaska, except at high altitudes, is almost entirely in the form of rain. In the Ketchikan district snow seldom lies on the ground more than a few hours. There are almost no meteorologic data available for the Ketchikan district proper, though records have been kept for many years in Sitka. Ketchikan, which lies about 300 miles south of Sitka, is somewhat warmer, and probably has a greater precipitation. The following tables summarize the meteorologic data available in regard to this region, and make comparisons with better-known regions of the world.[b]

[a] A report to Congress on Agriculture of Alaska, Bull. 48, U. S. Department of Agriculture, Office of Experiment Stations.

[b] Op. cit., pp. 7 and 8.

*Average temperatures in southeastern Alaska and other regions.*

[In degrees Fahrenheit.]

| Locality. | January. | February. | March. | April. | May. | June. | July. | August. |
|---|---|---|---|---|---|---|---|---|
| Wrangell [a] | 26.2 | 30.8 | 31.6 | 42.7 | 49.3 | 55.3 | 58.2 | 57.5 |
| Sitka [a] | 32.9 | 33.6 | 37.1 | 42.1 | 47.6 | 51.9 | 55.1 | 56.4 |
| Juneau [a] | 27.5 | 24.7 | 33.5 | 40.1 | 47.6 | 53.6 | 56.6 | 55.0 |
| Killisnoo [a] | 27.7 | 26.8 | 33.1 | 36.9 | 45.6 | 51.6 | 55.2 | 54.4 |
| Port Angeles, Wash. [b] | 34.7 | 36.7 | 41.7 | 45.6 | 50.6 | 54.0 | 56.6 | 56.8 |
| Trondhjem, Norway [c] | 27.4 | 26.8 | 28.6 | 37.9 | 45.8 | 53.6 | 57.2 | 56.3 |
| Bergen, Norway [c] | 34.1 | 32.2 | 35.4 | 43.7 | 48.9 | 55.0 | 57.9 | 57.5 |
| Christiania, Norway [c] | 24.1 | 23.9 | 29.5 | 39.9 | 50.9 | 59.9 | 62.6 | 60.6 |
| Helsingfors, Finland [d] | 20.9 | 18.8 | 26.2 | 34.8 | 44.1 | 56.9 | 61.9 | 58.3 |
| Stockholm, Sweden [e] | 33.5 | 29.5 | 33.8 | 39.5 | 52.5 | 57.0 | 59.1 | 59.3 |
| Scotland [f] | 37.1 | 38.4 | 39.4 | 44.1 | 49.0 | 54.8 | 57.1 | 56.6 |
| Orkney Islands [g] | 38.5 | 38.2 | 40.3 | 43.3 | 47.8 | 52.8 | 55.1 | 55.0 |

| Locality. | September. | October. | November. | December. | Average. | Total temperature May 1 to Sept. 30. | Sum of effective temperatures May 1 to Sept. 30. |
|---|---|---|---|---|---|---|---|
| Wrangell [a] | 52.3 | 45.9 | 33.5 | 32.9 | 43.0 | 8,343.0 | 1,764.0 |
| Sitka [a] | 52.3 | 46.2 | 38.9 | 35.8 | 44.2 | 8,058.1 | 1,479.1 |
| Juneau [a] | 49.9 | 41.9 | 31.2 | 29.3 | 40.9 | 8,040.2 | 1,461.2 |
| Killisnoo [a] | 47.8 | 41.1 | 33.4 | 30.1 | 40.3 | 7,793.2 | 1,214.2 |
| Port Angeles, Wash. [b] | 52.7 | 47.7 | 42.4 | 38.2 | 46.1 | 8,285.0 | 1,671.0 |
| Trondhjem, Norway [c] | 50.0 | 41.1 | 32.7 | 27.5 | 40.6 | 8,046.3 | 1,465.3 |
| Bergen, Norway [c] | 52.7 | 45.1 | 38.5 | 34.7 | 44.6 | 8,324.3 | 1,745.3 |
| Christiania, Norway [c] | 52.7 | 41.9 | 32.1 | 25.6 | 41.9 | 8,775.1 | 2,196.1 |
| Helsingfors, Finland [d] | 50.5 | 43.9 | 33.7 | 21.7 | 39.2 | 8,315.3 | 1,736.3 |
| Stockholm, Sweden [e] | 53.6 | 40.6 | 35.6 | 27.3 | 43.4 | 8,615.9 | 2,074.9 |
| Scotland [f] | 52.8 | 46.4 | 40.6 | 37.8 | 46.1 | 8,271.7 | 1,692.7 |
| Orkney Islands [g] | 52.5 | 47.5 | 42.6 | 40.9 | 46.2 | 8,053.9 | 1,474.9 |

[a] United States Weather Bureau compilation.
[b] Monthly Weather Review, United States Weather Bureau, 1893.
[c] Landrugsdirekt. Beretning, 1893.
[d] Ofver. Finska Vetenskaps Soc. Forhandlinger (average, 1869–1878).
[e] Meteror. Iaktag. i Sverige k. Svensk Vetens. Akad., 1890.
[f] Trans. Highland and Agl. Soc. Scotland, 1895.
[g] Trans. Highland and Agl. Soc. Scotland, 1874.

*Average precipitation in southeastern Alaska and other regions.*

| Locality. | January. | February. | March. | April. | May. | June. | July. |
|---|---|---|---|---|---|---|---|
| | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| Wrangell | 3.43 | 5.70 | 2.58 | 3.87 | 3.06 | 3.56 | 3.98 |
| Sitka | 7.95 | 8.02 | 7.78 | 5.03 | 3.89 | 3.87 | 4.14 |
| Juneau | 10.59 | 4.80 | 6.49 | 5.25 | 7.36 | 4.99 | 5.25 |
| Killisnoo | 5.26 | 5.03 | 4.39 | 2.56 | 2.80 | 2.00 | 3.53 |
| Port Angeles, Wash | 4.90 | 3.33 | 2.53 | 1.90 | 1.05 | 1.50 | 0.27 |
| Trondhjem, Norway | 3.36 | 2.28 | 2.52 | 2.20 | 2.32 | 2.48 | 2.56 |
| Bergen, Norway | 6.93 | 5.55 | 4.33 | 3.78 | 4.09 | 4.37 | 6.06 |
| Christiania, Norway | 1.22 | 0.94 | 1.06 | 1.10 | 1.77 | 2.04 | 3.34 |
| Helsingfors, Finland | 1.47 | 1.20 | 1.16 | 1.39 | 1.67 | 1.72 | 2.09 |
| Stockholm, Sweden | 0.88 | 0.44 | 1.34 | 2.85 | 3.12 | 1.58 | 2.62 |
| Scotland | 3.95 | 3.00 | 2.78 | 2.15 | 2.29 | 2.50 | 3.11 |
| Orkney Islands | 4.29 | 3.11 | 2.71 | 1.86 | 1.55 | 2.17 | 2.62 |

| Locality. | August. | September. | October. | November. | December. | Total. | Total precipitation, May 1 to Sept. 30. |
|---|---|---|---|---|---|---|---|
| | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| Wrangell | 2.62 | 9.58 | 8.16 | 11.03 | 9.44 | 67.01 | 22.80 |
| Sitka | 6.67 | 10.94 | 12.96 | 10.77 | 8.52 | 90.54 | 29.51 |
| Juneau | 7.35 | 10.04 | 8.49 | 8.78 | 7.38 | 86.77 | 34.99 |
| Killisnoo | 4.80 | 6.39 | 6.92 | 6.43 | 5.84 | 55.92 | 19.52 |
| Port Angeles, Wash | 0.85 | 2.10 | 2.91 | 3.52 | 5.35 | 29.35 | 5.77 |
| Trondhjem, Norway | 2.59 | 3.27 | 4.29 | 3.50 | 4.25 | 35.60 | 13.22 |
| Bergen, Norway | 6.85 | 8.26 | 8.78 | 6.73 | 7.44 | 69.13 | 29.63 |
| Christiania, Norway | 2.87 | 2.99 | 2.56 | 1.89 | 1.26 | 22.56 | 12.92 |
| Helsingfors, Finland | 2.71 | 2.20 | 2.57 | 2.42 | 1.61 | 22.25 | 10.39 |
| Stockholm, Sweden | 4.57 | 1.27 | 3.28 | 2.65 | 0.69 | 25.22 | 13.16 |
| Scotland | 3.55 | 3.67 | 4.05 | 3.82 | 3.97 | 38.83 | 15.12 |
| Orkney Islands | 2.84 | 2.72 | 4.85 | 3.89 | 4.33 | 36.95 | 11.94 |

Many years ago some records were kept at Fort Tongass, a military post of the United States, on Tongass Island, at the mouth of Portland Canal, in the southern part of the Ketchikan district. These have been summarized in the following table and a comparison made with more northerly lying localities of southeastern Alaska:

*Meteorologic observations in southeastern Alaska.*

| | Mean temperature. | Mean precipitation. |
|---|---|---|
| | *Degrees.* | *Inches.* |
| Fort Tongass [a] | 46.5 | 118.30 |
| Fort Wrangell [a] | 42.2 | 60.54 |
| Juneau [b] | 40 | 67.82 |
| Sitka [a] | 43.3 | 81.69 |

[a] Dr. William H. Dall, Pacific Coast Pilot, Alaska, Appendix I, Meteorology and Bibliography, Washington, 1879.

[b] Fourth Report on the Agricultural Investigations in Alaska, 1900, by C. C. Georgeson, Bull. No. 94, U. S. Dept. of Agricult., Office of Experiment Stations. Observations of temperature Jan.–Dec., 1899. Observations of precipitation Jan.–Oct., 1900.

The facts stated show conclusively that the climatic conditions in the Ketchikan region leave little to be desired for the development of mining enterprises. While the abundant precipitation is rather trying to those who are accustomed to a more arid climate, yet this rainfall, though a drawback to the prospector, does not interfere with mining developments. In fact, it is an advantage, as it gives ample water. Water powers can be used and all mining operations can be continued throughout the year. Except at high altitudes there is no snow to interfere with transportation or excavations.

Southeastern Alaska is heavily forested up to an altitude of about 3,000 feet. The diameters of the larger trees vary from 3 to 5 feet, though trees with a diameter of 6 feet, or even more, are to be found in the Ketchikan district. Hemlock is the most common species, but spruce trees are almost as plentiful and of greater commercial value. Red cedar is common in the Ketchikan district, and the valuable yellow cedar is also found, but more sparingly. Of the deciduous trees, only black alder and a cottonwood (balsam) are plentiful. At one locality in the Ketchikan district a few white birches were observed. The undergrowth in the region is often very dense and the ground is heavily carpeted with moss. Those who have occasion to penetrate the southeastern Alaskan forests have their attention most frequently and unpleasantly called to the prickly "devil's club."

Everywhere in southeastern Alaska, and especially in the Ketchikan district, there is an ample supply of timber for all local use, including mining. The spruce, while it does not afford a particularly high grade of timber, is extensively used for building purposes. The hemlock has been less used up to the present time. The

cedar has an export value, but the law permits the cutting of timber on Government lands only for local use.

While it is not within the scope of this report to treat of the agricultural possibilities of the region, yet it seems worth while to draw attention to the fact that the influx of a mining population will undoubtedly lead to agricultural development. On Prince of Wales Island two small farms have been cultivated, and, in spite of the cheap freights, have successfully competed with the vegetables brought from Puget Sound. Both climate and soil are adapted to certain kinds of farming. While the topography is such that there are few large arable tracts, there are untold opportunities for the development of small farms and gardens. Those interested in this matter are referred to the able reports of Professor Georgeson, of the Department of Agriculture, who has made a special study of the agricultural possibilities of Alaska.

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# A RECONNAISSANCE OF THE NORTHWESTERN PORTION OF SEWARD PENINSULA, ALASKA

BY

ARTHUR J. COLLIER

WASHINGTON
GOVERNMENT PRINTING OFFICE
1902

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# A

# RECONNAISSANCE

OF THE

# NORTHWESTERN PORTION OF SEWARD PENINSULA, ALASKA

BY

ARTHUR J. COLLIER

WASHINGTON

GOVERNMENT PRINTING OFFICE

1902

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# A RECONNAISSANCE OF THE NORTHWESTERN PORTION OF SEWARD PENINSULA, ALASKA.

By ARTHUR J. COLLIER.

## INTRODUCTION.

In response to an urgent demand by the public, the Geological Survey, in 1900, undertook a topographic and geologic reconnaissance of the southern half of the Seward Peninsula.[a] The area mapped embraced the more important gold fields of the peninsula. The topographic map made in 1900 included the drainage of Bering Sea from Cape Darby to Port Clarence, the southern drainage of Grantley Harbor and Imuruk Basin, and the northern drainage of Norton Sound. A geologic reconnaissance was also made of the York mining district and of part of the Kuzitrin drainage.

In view of the northern extension of these gold fields it was deemed desirable that the northern part of the peninsula should be investigated, and a party was organized for this purpose in 1901. This party, to which the writer was detailed as geologist, was placed under the leadership of Mr. T. G. Gerdine, topographer; Mr. D. C. Witherspoon acted as assistant topographer, and Ed. Brown, Robert Baskins, Samuel Conrad, J. G. De Forest, and E. Goodall were engaged as camp hands. Twelve horses were provided for the transportation of the camp outfit in the field. It was thought that a party thus organized and equipped would be able to cover a larger area than any one party of the previous season, when canoes and men were used for transportation. This expectation was realized, although a backward and unusually stormy season made the work difficult and prevented the accomplishment of the entire plan,[b] which contemplated the completion of the survey of the peninsula.

[a] See Preliminary Report on the Cape Nome Gold Region, Alaska, by F. C. Schrader and Alfred H. Brooks; U. S. Geol. Survey, 1900. Also Reconnaissances in the Cape Nome and Norton Bay Regions, Alaska, in 1900, by Alfred H. Brooks, George B. Richardson, Arthur J. Collier, and Walter C. Mendenhall; U. S. Geol. Survey, 1901.

[b] The average temperature as observed in 1901 was 41° in July, 43½° in August, and 40° in September. The mean temperature at Port Clarence, as obtained from observations covering four years, is 51° for July, 49° for August, 41° for September. The number of rainy days in July, August, and September, 1901, as observed by the United States Geological Survey party, was 36. The mean number of rainy days at Port Clarence for these months is 29. Cf. "Climatic notes" in Reconnaissances in the Cape Nome and Norton Bay Regions, Alaska, in 1900.

The party assembled in Seattle and on May 30 embarked on the steamship *Senator*, bound for Nome and Port Clarence. On June 9 the Aleutian Islands were passed, and about midnight of that day floe ice was encountered in Bering Sea. Several attempts were made to navigate through the ice, but it was found impossible, and for six days the ship lay to in the vicinity of St. Paul Island surrounded by the ice pack.

The ship finally dropped anchor at Nome on June 16. It was the first of the fleet of large steamers to arrive, and it was almost immediately surrounded by a multitude of small boats from the shore, crowded with men who had spent the long winter in the Arctic region and were anxious to greet the new arrivals from the outside world. The winter of 1900–01 had been an unusually severe one, and had begun to break only a few days before our arrival. There were still snow drifts in the streets of Nome and blocks of ice along the shore, while the hills back of the town were yet white with snow. As Port Clarence was still frozen in, the steamer could not make a landing there, and as it was impossible to travel overland with horses, owing to the ice in the creek beds and to the absence of grass or other forage, it was decided to land the outfit at Nome, which was accomplished on June 20.

Five days later the party started from Nome for Port Clarence; two men went by land with the horses and the remainder in a whaleboat with most of the supplies. Stormy weather delayed the boat, so that the entire party was not assembed in Teller until July 12. At this point work was begun. The signals erected the year before by the Coast and Geodetic Survey were repaired and used as a base for the control of the topographic work. The party left Teller on July 14 and moved westward along the coast toward Cape York. Progress was slow, owing to rainy and foggy weather, which greatly interfered with the work of both the topographers and the geologist, and to the necessity of carrying a supply of grain for the horses, the grass being very poor. A week later the larger section of the party had to be sent back from the forks of the Don River for more horse feed. The remainder spent the time in exploring and mapping the southern face of the York Mountains and the head of the Don River.

On July 24 Mr. Gerdine, Mr. Witherspoon, and the writer, with two men and a light camp outfit carried on three horses, left the main party, which was instructed to move northward by double-tripping with the heavier part of the supplies, and proceeded around the north side of the York Mountains to the head of the Anikovik River in the York mining district. From this point Mr. Gerdine went northward to the main camp near the forks of the Mint River, while Mr. Witherspoon and the writer spent several days in mapping the western border of the York Mountains. During the season of 1900 Mr. Alfred H. Brooks had spent a few days in this region,

OUTLINE MAP OF SEWARD PENINSULA

SHOWING AREA OF LARGER SCALE MAPS

Scale

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feet. Marys Igloo was reached on September 3. This place, the former winter home of a well-known Eskimo woman, is at the head of steamboat navigation on the Kuzitrin River, and has within a year or two become a settlement of some importance. Here the stock of provisions was replenished from supplies shipped to this point from Nome and kept in storage by Mr. A. D. Nash, who was doing a general freighting business on the Kuzitrin River. The horses here rapidly recuperated from the privations of the long trip, as forage was abundant. At Marys Igloo the party was again divided, Mr. Witherspoon with two men going westward to map the lower basin of the Agiapuk and to return to Nome by way of Teller and the beach, while the remainder of the party made a hasty trip northward.

Mr. Witherspoon's party successfully crossed the Agiapuk River at a point where its broad alluvial basin narrowed down between low bluffs, examined the mines on Allene Creek, and arrived at Nome about September 23, having accomplished its task.

The remainder of the party proceeded up the Kuzitrin River to Lanes Landing, where there is a small settlement, and thence took the wagon road to Quartz Creek. Near this point a halt of two days was made to examine the placers in the vicinity and to occupy Coffee Dome, a low mountain which is one of the prominent landmarks of the Kugruk district. Thence the party proceeded northward to the junction of Windy Creek with the Kugruk River and up the Kugruk River to the mouth of Taylor Creek, making a side trip to the summit of Baldy Mountain. On September 14 camp was made about 3 miles from Midnight Mountain on Schlitz Creek, tributary to Shishmaref Inlet. Here, during a halt of two days, the writer, with Mr. De Forest, visited the hot springs, about 7 miles to the north; and Mr. Gerdine occupied Midnight Mountain, which commands a view of the whole northern coast of the peninsula from Ear Mountain to Goodhope Bay. On September 17 the party proceeded southward by a long march to the North Fork of the Kugruk, crossing Taylor and Harris creeks. Here a halt of one day was made while the writer visited the mines on Boulder Creek, about 8 miles to the south. On September 19 the camp outfit was sent by way of Baldy Mountain and Dahl Creek to Lanes Landing. The plan was for Mr. Gerdine and the writer to secure some kind of transportation down the Noxapaga and Kuzitrin rivers, and thus to complete the mapping of those rivers, and then to rejoin the party at Lanes Landing. After a delay of three days at Noxapaga, during which time hasty trips were made to Garfield Creek and to the edge of some lava beds on the Kuzitrin, transportation was secured down the river through the courtesy of Mr. A. D. Nash, and during the journey the numerous bends were mapped. On September 28, at 11 p. m., Lanes Landing was reached, over 100 miles by river having been traversed to gain an air-line distance of about 25 miles. Here the rest

*A.* TELLER, FROM POINT OF SAND SPIT.

*B.* VALLEY OF QUARTZ CREEK CUT IN HIGH GRAVEL BENCH.

as coastal plains and as inland basins, and are built up from gravels derived from the upland portion.

The central upland portion is characterized by broad benches and flat-topped hills, representing remnants of uplifted and dissected plains. The maximum elevation in the northern portion of the peninsula is found in Brooks Mountain at 2,900 feet.

These features will be further discussed under physiography. Some small mountain masses and isolated buttes, with relief of from 500 to 1,500 feet, are scattered over the upland plateaus with no definite system of arrangement. In most instances these represent harder members of the bed rock, which have resisted erosion. The York Mountains, covering an area of about 100 square miles, are a rugged mountain mass, attaining at their highest point, in Brooks Mountain, an elevation of 2,900 feet; while the buttes are represented by Mukacharni, Cape Mountain, Cone Hill, Ear Mountain, Midnight Mountain, and others, all of which will be considered in more detail in other parts of this report.

Between the drainage basins of the Agiapuk and Kugruk rivers a series of high hills and ridges bearing in a north-south direction culminates in Kugruk Mountain, which has an elevation of 2,767 feet.

## GENERAL GEOLOGY.

### OUTLINE.

The areal distribution of the various formations and their stratigraphic relations are indicated on the accompanying geologic map and section (Pl. III). As the map embraces an area of nearly 4,000 square miles, and as only seventy days were spent in the field work, and most of these were stormy, the conclusions reached must be regarded as only tentative and the boundaries indicated as only approximate. The scarcity of outcrops in some parts of the region added to the difficulties of the work. The classification of the stratigraphic succession in general is the same as that adopted by Mr. Brooks[a] in 1900. It has been possible, however, because of the additional stratigraphic and paleontologic evidence obtained, to subdivide the terranes which were grouped together by Brooks under the name Nome series. The following table shows the stratigraphic equivalents of the various subdivisions made by Brooks, Mendenhall,[b] and the writer:

[a] Reconnaissances in Cape Nome and Norton Bay Regions, Alaska, in 1900, pp. 27-31.
[b] Idem, pp. 27-31, 199-207.

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*Correlation of geologic formations in Seward Peninsula.*

<table>
<tr><th colspan="2">Collier, northwest portion, 1901.</th><th colspan="2">Brooks, southern portion, 1900.</th><th colspan="2">Mendenhall, eastern portion, 1900.</th></tr>
<tr><td>Pleistocene.</td><td>Sands and gravels.</td><td>Pleistocene.</td><td>Sands and gravels.</td><td>Pleistocene.</td><td>Muds, sands, and gravels.</td></tr>
<tr><td></td><td></td><td></td><td></td><td>Tertiary?</td><td>Unaltered sediments.</td></tr>
<tr><td>Upper Silurian.</td><td>Kugruk group.</td><td rowspan="3">Mesozoic and Paleozoic.</td><td rowspan="3">Nome series.</td><td rowspan="4">Mesozoic and older.</td><td rowspan="4">Metamorphic series.</td></tr>
<tr><td>Lower Silurian.</td><td>Port Clarence limestone.</td></tr>
<tr><td rowspan="2">Older than Silurian.</td><td>Kuzitrin series.</td><td rowspan="2">Paleozoic and older.</td></tr>
<tr><td>Kigluaik series.</td><td>Kuzitrin series.</td><td>Kigluaik series.</td></tr>
</table>

The above table shows that four subdivisions have been made of the sedimentary bed rocks of the northern portion of the Seward Peninsula. The Kigluaik series is the oldest, and is made up of white crystalline limestones and mica-schists. Succeeding this, apparently conformably, is the Kuzitrin series, made up of arenaceous and argillaceous sediments. These two series are identical with those described by Brooks. The Kuzitrin series is overlain by the Nome series, probably unconformably, as suggested by Brooks. The Nome series has been here subdivided into two conformable groups, the lower named the Port Clarence

limestone and the upper called the Kugruk group. The Port Clarence limestone, which is blue and almost unaltered, was found to contain Lower Silurian fossils. The Kugruk group is made up of limestones and calcareous beds, with some argillites, which are locally considerably altered. The unconsolidated sediments which have been assigned to the Pleistocene include sands, gravels, and alluvium, and need no special mention here.

Three classes of igneous rocks have been recognized in the region and indicated on the map. The oldest are intrusives of various types, which are usually schistose, and these have been grouped together under the field term greenstone. The granites form a second group, and probably represent Mesozoic intrusions. These two classes were recognized by Brooks, but the third, which comprises Pleistocene lavas, was not represented in the region mapped in 1901.

In the northern part of the peninsula the earliest crustal movements produced a series of folds whose axes run approximately north and south. This deformation probably took place in Paleozoic times, and was accompanied by extensive intrusions of greenstone. A later period of disturbance, probably during the Mesozoic, produced folds whose axes are transverse to the earlier system. This was accompanied by the intrusion of some large masses of granite.

## STRATIGRAPHIC SUCCESSION.

### KIGLUAIK SERIES.

The Kigluaik series was named and described in the report cited, and the investigations made by the writer have not added much information concerning it. Its type section is in the Kigluaik Mountains, where it consists of white crystalline limestones with some interbedded mica-schists. This series occupies a considerable belt in the southeastern part of the area under consideration, where it, together with the associated granite, forms the main mass of the Bendeleben Mountains. On the eastern flank of Cape Mountain, near Cape Prince of Wales, it is again exposed by the erosion of an anticlinal fold. This occurrence was not examined by the writer, but was described by Mr. Brooks as a belt of crystalline limestone, often beautifully banded and containing intercalated beds of mica-schist, and intruded by a large granite batholith. This limestone is the oldest rock in the York region, and it and the granite of Cape Mountain have the same relation as the limestones and granites in the Kigluaik Mountains. It was therefore tentatively correlated by Mr. Brooks with the Kigluaik series.

### KUZITRIN SERIES.

The type rock of this series is a graphitic quartzite, or quartz-schist, sometimes passing into a graphitic flag, or even a slate. The Kuzitrin series forms a well-

defined stratigraphic unit, which is recognized and named in the previous report. The relation of these rocks to the underlying Kigluaik series was not definitely established, but such evidence as there is indicates that they are conformable. On the south side of the Kigluaik Mountains they were found standing at a high angle and forming a belt 1 to 2 miles wide flanking the mountains. At this place the thickness of the series was estimated at approximately 2,000 feet.

Two considerable belts and a number of small areas of these rocks have been identified in the northern part of the peninsula. The southern belt, extending eastward from Port Clarence to the Kugruk River, forms a part of the northern limit of the great anticlinal uplift of the Kigluaik and Bendeleben mountains. On the accompanying map it is interrupted by the Pleistocene deposits, and by unmapped areas which have not been colored.

The slates which are found covering a large area in the vicinity of York are less highly metamorphosed than those in the above localities, but on stratigraphic and lithologic grounds they were tentatively correlated with the Kuzitrin series.[a] All the evidence collected during the season of 1901 tends to confirm that opinion.

The Kuzitrin series is exposed in three other smaller areas, where it is associated with granitic intrusions, and probably occurs in dome-shaped uplifts accompanied by more or less faulting. These areas were not examined in detail, and it seems possible that beds belonging to the underlying Kigluaik series may be exposed in the central portions of the domes. In the Kuzitrin series of the York region there are a number of intrusive masses of greenstone, believed to be altered gabbros, apparently occurring as dikes and sills. Similar rocks, though of a more diabasic character, were found in the Bluestone region southeast of Port Clarence, and in general it can be said that greenstone intrusives are not uncommon in the Kuzitrin series.

It will be shown below that the succeeding beds, which are Lower Ordivician, probably bear an unconformable relation to the Kuzitrin series. This would make the Kigluaik and the Kuzitrin series Cambrian or pre-Cambrian.

## NOME SERIES.

*Introduction.*—In the report of 1900 a great thickness of limestones, graphitic and calcareous schists, with some intrusive greenstones and chloritic schists of undetermined origin, were grouped together under the name Nome series.[b] The stratigraphic relation of the Nome series to the underlying Kuzitrin series has not been definitely established, though from the evidence collected in 1900 on the south

[a] Reconnaissances in the Cape Nome and Norton Bay Regions, Alaska, in 1900, p. 29.
[b] Ibid.

slope of the Kigluaik Mountains, near the head of the Kruzgamepa, it appears to be one of unconformity. In the York region, as will be shown, a similar relation of the two series seems to obtain. Where originally described, in the southern part of the peninsula, the basal member of the Nome series is a flaggy limestone or calcareous schist, probably less than 1,000 feet in thickness. Above this terrane a few hundred feet of graphitic limestones and phyllites were found, succeeded by heavily bedded limestones aggregating 1,000 or 2,000 feet in thickness. The upper part of the Nome series, of which no measure of thickness was obtained, is made up of thin-bedded limestones, calcareous schists, and mica-schists. A few fragmentary fossils were found in the lower part of the series, which were determined as Ordovician. It was recognized by Brooks[a] and his associates that the Nome series included terranes of widely different ages, but the character of the field work did not permit of any subdivisions at that time. Attention was called to the large number of greenstones occurring in the series, and also to the comparatively local character of its metamorphism. The investigation of the last season has enabled the writer to subdivide the Nome series into the Port Clarence limestone and the Kugruk group.

*Port Clarence limestone.*—North of Port Clarence the basal member of the Nome series was found to be a gray, earthy limestone, which over large areas exhibits but little evidence of metamorphism. This limestone occupies a large area, including the York Mountains, near the western extremity of the peninsula. Within this belt are a few small areas of Kuzitrin rocks which have been exposed by dome-like uplifts.

A short distance north of Grantley Harbor some quartz-schists which belong to the Kuzitrin series are found outcropping near the exposures of the Port Clarence limestone. The quartz-schists have steep dips, and are considerably indurated, while the Port Clarence limestone consists of blue limestone which has been but little altered. There can be but little doubt that the relation of the two terranes is one of unconformity, the limestone being the younger.

Along the western margin of the Port Clarence limestone belt the contact relations with the Kuzitrin series also point toward unconformity. The contact, which was traced for several miles, there follows the western face of the York Mountains; and while the evidence was not decisive, it all pointed toward a structural break between the two formations. The arenaceous rocks of the Kuzitrin series along this line of contact are indurated and have a highly developed cleavage, while the Port Clarence limestone, which forms the mass of the mountains to the east, is little altered and has low dips. The relations are more or less obscured by the large intrusion of greenstone which occurs near the contact of

[a] Reconnaissances in the Cape Nome and Norton Bay Regions, Alaska, in 1900, p. 31.

*A.* CRUMPLED LIMESTONE, BROOKS MOUNTAIN.

*B.* PORT CLARENCE LIMESTONE, NULUK RIVER.

About 10 miles east of this locality, and along the east side of the American River Basin, the bed rock was found to consist of highly altered limestones and graphite-schists and mica-schists, dipping toward the west. These rocks were of the type common in the Nome series of the southern half of the peninsula. The stratigraphic evidence is not sufficient to justify any conclusions in regard to their relations with the Port Clarence limestone.

Between the head of the Nuluk River and Ear Mountain very few exposures of bed rock were seen. The region is to a large extent covered by gravel and tundra. Some depressions were seen on the broad ridge, which indicate limestone sinks beneath the gravel.

Ear Mountain consists of rocks which probably belong with the Kuzitrin series. The relation of these rocks to the schistose limestones found to the southeast of Ear Mountain was not determined. These latter limestones are highly crystalline and often schistose, but are practically homogeneous and represent a great thickness of strata. The bedding is often obscured by jointing and cleavage. The dips, where they can be determined, are high. Above these highly altered limestones there is a bed of graphitic schist, above which the bed rock consists of alternating beds of schist and limestone common in the Nome series, in which the limestones predominates. If these highly altered limestones which lie to the south and east of Ear Mountain are correlated with the Port Clarence limestone, then the graphitic, micaceous, and calcareous schists and limestones overlying it belong to the Kugruk group.

The age of the Port Clarence limestone was definitely determined by the fossils from several localities. These were submitted to Mr. Charles Schuchert, of the National Museum, who reports as follows:

"Loc. 26. July 20. Two miles southwest of forks of the Don River. *Porambonites*, probably *P. intercedens* Pander; *Columnaria* with large corallites, and *Bythotrypa?* sp. undet.

"Loc. 28. July 21. Mountain 4 miles north of Rapid River. *Illænus* near *I. tauricornis* but much smaller; *Illænus* sp. undet.; and a lithistid sponge on the order of *Calathium*.

"Loc. 45. July 23–24. Don River 4 miles north of Tozier Creek. *Maclurina*, probably *M. manitobensis* Whiteaves; *Columnaria* with small corralites; *Halysites catenularia* Linne; *Syringopora* sp. undet.; *Streptelasma?*; and an undetermined *Lophospira*.

"Loc. 77. August 9. Bluff above Nuluk River, latitude 65° 41′, longitude 166° 20′. *Orthis*, probably *O. parca* of European Russia.

"Loc. 78. August 10. Foot of talus slope, Nuluk River. A large section of an undetermined gasteropod.

"Loc. 76. August 10. Bowlder from gravel of Nuluk River. Fragments of a large trilobite. Undeterminable.

*A*. SCHISTOSE LIMESTONE, KUGRUK GROUP, HEAD OF PORTAGE CREEK.

*B*. SCHISTOSE LIMESTONE, KUGRUK GROUP, BUDD CREEK

"Locality 163 indicates a second formation younger than any of the above-described lots. The rock has undergone considerable alteration, so that the fossils are mostly undeterminable. However, the presence of a coral like *Cladopora* or *Striatopora* indicates either Upper Silurian or Devonian. No coral of this nature is known to me in the Lower Silurian."

This evidence, as far as it goes, shows that the group is in part of Upper Silurian or of Devonian age. As the Kugruk group includes all of that portion of the Nome series as originally defined which lies above the Port Clarence limestone, it may be in part Mesozoic, for in the earlier report evidence is presented which goes to show that the upper beds of the Nome series are in part Mesozoic.[a] No additional facts bearing on this point were observed during last season's work.

The rocks which make up the Kugruk group are, as a rule, more altered than the Port Clarence limestone, which is believed to be the older formation. This anomaly is rather difficult to explain, but can perhaps be assigned to the progressive increase in degree of metamorphism which is found in passing from west to east in this province. In the York Mountains the strata are usually only gently folded and little indurated, while to the east of the American River, where the Kugruk beds are developed, the dips are often steep and the rocks considerably altered. As a concomitant to the more disturbed condition in the eastern province the greenstone intrusives are more abundant and have themselves produced more or less metamorphism. These facts bear out the statement made in the previous report,[b] that in the Seward Peninsula the forces which produced metamorphism acted very locally.

As the limited field work done in the region did not permit of working out the structure of the Kugruk rocks in detail, it has been thought best to add the following more or less detailed but fragmentary descriptions.

On the east side of the American River, Budd and Igloo creeks cut across the strike of a series of limestones interbedded with graphitic and calcareous schists, with some small sills of greenstone. The dips measured vary from horizontal to 70°. The topography is determined by the bed-rock structure, the principal features being a series of north-south ridges parallel to the prevailing strikes. Between the drainage basins of the American and Kugruk rivers these strike ridges form a sharp divide. Kugruk Mountain, at the northern end of this divide, is composed of a great thickness of highly metamorphosed quartz-mica-schist, probably an altered sediment. It is surrounded by crystalline limestones, which on the west side dip toward the west, away from the axis of the ridge. In this mountain the bedding is wholly obscured by the secondary foliation or schistosity. The limestones at the east base of the mountain were seen only from a distance, so that

[a] Reconnaissances in the Cape Nome and Norton Bay Regions, Alaska, in 1900, p. 31.
[b] Idem, pp. 34–36.

*A.* BEDDING AND CLEAVAGE IN KUGRUK LIMESTONE, SOUTH OF IGLOO CREEK.

*B.* FROZEN SILTS CONTAINING SPRUCE LOGS ON QUARTZ CREEK.

tion, including mica-, graphitic, and quartz-chlorite-schists. These beds have been folded into anticlines and synclines with north-south axes.

In general the limestone and schist of the Kugruk group east of the American River are more highly altered than the Port Clarence limestone, and consist of beds which are variable in their lithologic character, while the Port Clarence limestone is nearly pure. The Port Clarence limestone is known to be of Lower Silurian age, while Upper Silurian or Devonian fossils have been found in the rocks of the Kugruk group.

## SURFICIAL DEPOSITS.

### GENERAL DESCRIPTION.

Unconsolidated material, consisting of gravels, sands, and silts, constitutes the most widely distributed terrane of the region. These deposits are as a rule plainly stratified, and while the individual exposures show no plication they have been subjected to a certain amount of deformation, as will be shown in the discussion of the physiography. A bed of black silt, varying from a few inches to 20 feet in thickness, in many places forms the topmost layer of the unconsolidated terrane. Remains of both mammoth and horse have been found in this silt, showing it to be of Pleistocene age. As this Pleistocene silt bed and the underlying sands and gravels make up a conformable series, they are probably all of Pleistocene age, and have been so represented on the accompanying map.

On the geologic map only the more extensive Pleistocene deposits are shown. These are of two types, represented by the coastal plain and the inland basins. The largest areas of Pleistocene are found in the Arctic coastal plain, the Port Clarence coastal plain, and the inland basins of several of the rivers tributary to Port Clarence.

In general the deposits in these large areas are similar; they consist largely of silts and sands, and near the margins often contain considerable gravel. The sand dunes and beach deposits can also properly be grouped with the coastal plain Pleistocene.

A third class of surficial deposits consists of the material forming the flood plains and benches of the rivers and creeks. These fluvial deposits grade on one hand into the coarse gravels of the smaller tributaries, and on the other into the finer material which characterizes the Pleistocene beds of the inland basins and coastal plains.

A fourth class of deposits includes all those on high benches and terraces which are not assignable to the action of existing streams. In addition to distinctly waterworn material, there are extensive deposits of bowlders, pebbles, and clay,

which mantle many of the plateau surfaces, and are in part produced by weathering, but in many instances include some waterworn material.

### COASTAL PLAIN DEPOSITS.

*Arctic coastal plain.*—This is a broad lowland bordering the Arctic coast from Cape Prince of Wales to Cape Espenberg. Along its southern margin it is composed of gravels derived from the adjacent bed rock. Near the coast the material becomes finer, and is made up of beach sand, sand dunes forming an important part of the deposits. A series of lagoons fringes the coast, which is separated from the Arctic Ocean by barrier beaches. Sand dunes are being built on these barrier beaches, which are encroaching on the lagoons from the seaward side, and the rivers and streams are filling up the lagoons from the landward side. The southern edge of the gravel deposits is serrate, since the gravels extend up the rivers and creeks and merge with the fluvial deposits of the flood plains. Their southern limit can be drawn approximately on topographic evidence, since the gravels are seldom found above the 200-foot contour.

The width of the coastal plain varies from about 5 miles near Cape Prince of Wales to 30 miles at Shishmaref Inlet. The depth of the Pleistocene deposits is not great along the southern edge, but it probably increases toward the coast. On the Mint, Nuluk, and Kugruk rivers isolated outcrops of the underlying bed rock were seen in the river banks several miles north of the southern edge of the gravels. Between the Pinguk and Nuluk rivers an island-like mass of bed rock is wholly surrounded by these deposits. South of Ear Mountain the Pleistocene extends over the divide between the Kugruk and Arctic rivers, almost cutting off the Ear Mountain area of bed rock from the hard formations adjacent on the south. In the silts which overlie the gravels and quite generally form the upper layer of these deposits mammoth bones are common. Mr. Charles A. Ruddy, who spent a part of the season of 1901 on Tuttle Creek, a tributary of the Kugruk, reports that they are abundant along that river. One large tusk in the silt, 15 feet below the surface, was partly exposed by the river cutting its bank. Mammoth teeth were seen by the writer on the Nuluk River, and they are reported to occur on other streams of the coastal plain region.

*Port Clarence coastal plain.*—This second coastal plain embraces a small lowland lying north of Port Clarence. It has a maximum width of about 5 miles, and extends from the mouth of the Rapid River to Grantley Harbor, a distance of about 24 miles. Along its southern edge the plain has a gravel escarpment about 20 feet high. The gravel is composed principally of pebbles derived from the Port Clarence limestones. The plain rises gradually toward the north, and along the base of the hills the gravel covering is only a few feet in thickness,

and rests on the upturned and truncated edges of Port Clarence limestones. Below the gravel escarpment, at the southern edge, the present beach has been formed. The beach is composed of sand and gravel derived from the escarpment. A large lagoon cuts it off from the mainland. This beach and lagoon have been formed since the elevation of the coastal plain.

### INLAND BASINS.

There are three extensive lowland basins in the province under consideration, which will be called the Agiapuk, Imuruk, and Kuzitrin lowlands. Except for the fact that they are inclosed by uplands, they resemble the coastal plains. They occupy broad basins, probably produced in part by deformation, and represent either lakes or estuaries which have been filled with gravel and silt deposits. The Agiapuk lowland is connected along the flood plain of the Agiapuk River with the lowland of the Imuruk Basin. A short canyon cut in bed rock intervenes between the Imuruk Basin and the Kuzitrin lowland. All three of these basins probably have the same history. They were formed at nearly the same time and their silt and gravel deposits are of Pleistocene age.

*Agiapuk lowland.*—This lowland, having an area of about 60 square miles, is located in the valley of the Agiapuk River, 25 miles above its mouth. It is dotted over with many lakes, and from the surrounding hills it has the appearance of a filled lake or estuary. As they approach the plain the tributaries of the Agiapuk River have broad valleys and flood plains. A mining shaft has been sunk on Allene Creek, one of the tributaries from the south, and is said to have failed to reach bed rock at a depth of 65 feet. Below a surface layer of gravel, blue clay containing bark and other driftwood was found. Mammoth bones are reported to be common within this basin.

*Imuruk lowland.*—This is a broad tundra-covered plain which surrounds Imuruk Basin and extends up the Kuzitrin and Kruzgamepa rivers, and has an area of about 200 square miles. The tundra is underlain by frozen silts of varying thickness, below which gravel and sand are exposed along the rivers. Along the northern edge of this plain, near the Mary River, there are some gravel mesas, about 50 to 100 feet high, which are regarded as remnants of an upper gravel plain that has been eroded away by the meandering of the river.

*Kuzitrin lowland.*—This is an area of lowland covering approximately 200 square miles on the north side of the Bendeleben Mountains and drained by the Kuzitrin River. The lowland is tundra covered, and underlain by silts, sand, and gravels, probably of no great depth. It is dotted over with many small lakes, probably formed by oxbows of the meandering creeks and rivers. Around the lowland area on the west, north, and east sides there is a higher gravel plain, from 50 to 150 feet above the lowland. A well-marked escarpment usually

separates this upper plain from the lowland. On the lowland surface, away from the margins, there are occasional gravel buttes, 50 feet or more in height, which at a distance resemble haystacks. These are regarded as remnants of the upper plain which have been left by erosion. At the edge of the upper plain transition phases between the plateau and the isolated buttes were noted in a few instances.

On Quartz Creek the gravels of the upper plain are overlain by frozen silts, in which bones of mammoth and horse have been found associated with the trunks of large spruce trees. A spruce log, said by the miners to be 5 feet in diameter and 80 feet long, was uncovered at this place.

Near the mouth of Turner Creek an isolated butte, known as Coal Hill, is composed largely of black peat containing many pieces of bark and branches of spruce trees. At the present time there is no spruce timber within the drainage of the Kuzitrin River. In Coal Hill there are seams of white sand interbedded with the peat, suggesting driftwood origin. However, the abundance of small twigs and some spruce cones would seem to indicate that the material has not drifted far. Associated with a spruce log which was found in the frozen silt on Quartz Creek, and which was followed by a tunnel for a distance of 80 feet, a part of the jaw and some teeth of a horse were found by Mr. A. H. Jose, who gave them to the writer to be placed in the National Museum. The specimens were submitted to Mr. F. A. Lucas, who reports in regard to them as follows:

"It is difficult—almost impossible—to identify horses from their teeth alone, but the teeth collected by you resemble those of *Equus complicatus*, which occurs throughout a large portion of the United States east of the Rocky Mountains. The extension of this species to Alaska would seem to give it an extraordinary range; still, this would not be greater than that of the bison in modern times and the elephant and mastodon in the Pleistocene. In the absence of more material this identification should be considered as provisional."

Teeth and tusks of the mammoth (*Elephas primigenius*), together with bones of other animals, are reported by the miners to be common in the placers along Quartz Creek.

### MAMMOTH REMAINS.

Elephant remains have been found in the silts of the Arctic coastal plain, in the Agiapuk Valley, and in the Kuzitrin Valley. In the Kuzitrin Valley they were associated with spruce logs and horse remains. Similar bones have been known from other parts of Alaska for many years, the most noted locality being at Elephant Point, on the south shore of Kotzebue Sound, about 50 miles northeast of the Kuzitrin Basin. At this point the remains of the horse, elephant, and bison were associated with those of the reindeer and musk ox.[a] This association of

[a] Dall, Bull. U. S. Geol. Survey No. 84, 1892, p. 264.

animals known to require such diverse climates would seem to indicate very unusual climatic and physical conditions.

Dr. Dawson[a] states that mammoth remains are found only in the nonglaciated portions of Alaska and the Yukon district of Canada. He also finds evidence that during the time of the mammoth there was a land connection between Alaska and the coast of Siberia. Whatever may have been the relation of the mammoth to the Glacial epoch, it seems certain, on account of the association of the remains with the evidence of forest growth, that a milder climate prevailed during at least a part of the mammoth period, and while these extensive gravel deposits were accumulating.

### ALLUVIAL SANDS AND GRAVELS.

Sand and gravel deposits, usually too small to be represented on the geologic map, occur to a greater or less extent in all the valleys. They are the product of stream action, and occur not only in the beds and flood plains of streams, but also as benches and terranes along the sides of the valleys above the present stream beds. The coarse gold of the placer mines is usually found in gravel deposits of this kind, which are described in more detail in the section on "Economic geology."

### ELEVATED SURFICIAL DEPOSITS.

Extensive gravel deposits at great elevations in places far removed from present stream beds have been noticed less frequently than in the southern part of the peninsula. In the neighborhood of Nome deposits of this kind have been extensively explored by prospectors, since they often carry placer gold. No search for them in the northern portions of the peninsula has yet been made by prospectors. Rounded pebbles and washed gravel at high elevations were noted in a few instances, the most striking cases being on the ridge between the forks of the Mary River, at 700 feet elevation, and in the divide between the waters of the Arctic and Kugruk rivers, south of Ear Mountain, at about 400 feet elevation.

Extensive plateaus have been developed over this region by erosion in a previous physiographic cycle.[b] These plateau surfaces are covered with semiangular gravels derived from the adjacent bed rock or with residual clay containing weathered fragments of the bed rock. Where the clay is found a tundra growth of moss often occurs, covering the surface.

### GLACIATION.

No evidence was found of general glaciation over the region explored. The surficial deposits over the upland portions, consisting of residual soil and gravels

[a] Notes on the occurrences of mammoth remains in the Yukon district of Canada and Alaska: Quart. Jour. Geol. Soc. London, Vol. L, pp. 1-9.

[b] See Physiography, pp. 34-39.

*A*. EAR MOUNTAIN, FROM BENCH AT 1,000 FEET ELEVATION.

*B*. THE EARS, GRANITE PINNACLES ON EAR MOUNTAIN.

derived from the adjacent bed rock, are regarded as evidence of nonglaciation. Erratic bowlders, such as were found in the southern portion of the peninsula and were attributed to floating ice, have not been found in the northern portion.[a]

The topography of the Bendeleben Mountains, the York Mountains, and Cape Mountain was noted by Brooks as indicating local glaciation. Similar indications of local glaciation were observed on Ear Mountain. During the season of 1901 no detailed examination was made of the Bendeleben Mountains. The explorations made last season show that the glaciers of the York Mountains were of very limited extent, as were also those of Cape and Ear mountains. The glacial deposits in no instances extend beyond the limits of the mountain valleys. Although small glaciers have undoubtedly existed in connection with these mountain masses, their deposits are of such limited extent that they can be neglected in this report.

## IGNEOUS ROCKS.

### INTRODUCTION.

All the types of igneous rocks described by Brooks[b] from the southern part of the peninsula were found in the northern portion of the region studied by him. In addition to these, recent basalts, occurring both as necks and surface flows, were found in a few localities, indicated on the geologic map.

### GREENSTONES.

The greenstones and greenstone-schists include a number of more or less altered intrusives, occurring both as sills and stocks. In the Kuzitrin slates near their contact with the Port Clarence limestones there are many intrusions, both in the form of dikes and sills, of greenstones which seem to be altered gabbros. Similar rocks were found intruded in the Kuzitrin slates at Cape Douglas. In the schists and limestones of the Kugruk group east of the American River there are many small bodies of greenstone, which are often highly schistose and composed chiefly of secondary minerals. In general they have been derived from basic igneous rocks, either diabase or gabbro, though in some cases the minerals present indicate that they were derived from more acid rocks. These greenstone-schists reach their greatest development along the Kugruk River, where they often contain phenocrysts of hornblende, and are designated "porphyry" by the miners of the region.

### GRANITIC AND RHYOLITIC INTRUSIVES.

In Cape Mountain, Brooks Mountain, and Ear Mountain, and near the hot springs north of Midnight Mountain, granites and fine-grained porphyries occur

[a] Reconnaissances in the Cape Nome and Norton Bay Regions, Alaska, in 1900, p. 46.
[b] Idem, p. 31.

as large intrusive masses and small dikes. The granite frequently forms needles and pinnacles on account of weathering along a double system of joints. Ear Mountain derives its name from two of these granite needles which have a semblance to the ears of some animal. Similar "ears" are found scattered over Ear Mountain and over the granite area near the hot springs. Small dikes of quartz-porphyry, probably connected with these granite intrusions, were found in the slates outside of the larger mass of granite.

The granite of Cape Mountain was described by Brooks as being coarsely crystalline, usually porphyritic, and as consisting essentially of quartz, microcline, and biotite. It has had considerable metamorphic effect on the adjacent limestones.

The granite in Brooks Mountain has not been examined microscopically. A small dike from this locality showed quartz and orthoclase phenocrysts in a groundmass composed of quartz and feldspar. In this mountain the limestones which lie adjacent to this intrusive are considerably altered.

The granites of Ear Mountain consist essentially of quartz, orthoclase, and biotite. A smaller body of pegmatite-granite is made up of quartz and orthoclase and plagioclase feldspars, while a small dike from the same region consists essentially of quartz and orthoclase phenocrysts in a groundmass of quartz and feldspar, with muscovite, largely secondary, and a secondary growth of feldspar surrounding the larger orthoclase phenocrysts. In the Ear Mountain granites a platy structure, brought out by the weathering, gives the rock a stratified appearance.

The granites of the hot springs region were not examined microscopically, but are similar in general type to those of Ear Mountain.

In Kugruk Mountain and in the limestone west of that mountain there are small dikes of rhyolite, which under the microscope show phenocrysts of quartz and feldspar. In the dikes which cut the schists the feldspar phenocrysts are replaced by chlorite, while in the dikes which occur in limestone the feldspar is replaced by calcite. These dikes are not associated with any granite mass which reaches the surface, and are the only cases of the kind seen in the area explored.

From the above description it will be seen that the acid intrusives have a wide distribution in the region, though they form no considerable masses such as occur in the Kigluaik and Bendeleben mountains farther south. The age of these intrusives has not been established, but they were probably injected during the last period of disturbance, which is believed to have been in Mesozoic time.

### BASALTS.

Basalts occur as small flows and volcanic necks at a number of localities. Mukacharni Mountain and the two small buttes to the east of this mountain, a

*A*. PLATY STRUCTURE IN GRANITE NEAR HOT SPRINGS.

*B*. PLATY STRUCTURE IN GRANITE, EAR MOUNTAIN.

small area on the east side of the California River, all north of Grantley Harbor, and a small hill about 2 miles east of the forks of the Don River are composed of unaltered basalts. These basalts are both compact and vesicular, and vary in color from gray to black. The vesicles are unfilled, and are often confused in weathered specimens with the cavities from which olivine phenocrysts have weathered. Under the microscope the rock is seen to consist of many olivine phenocrysts in a groundmass consisting of plagioclase feldspar, probably labradorite, and a more or less opaque aggregate in which augite and magnetite can sometimes be recognized, the former in short prisms.

Mukacharni Mountain and the two buttes to the east of it and the small hill to the east of Tozier Creek are volcanic necks cutting the schists and slates. The basalt areas west of Mukacharni Mountain and east of the California River are remnants of surface flows or sills, which have probably been erupted at the same time as the necks. The amount of erosion since these eruptions indicates that they took place in pre-Pleistocene time.

Between the Kuzitrin and the Noxapaga rivers extensive lava beds are reported by prospectors. These lava beds are reported to extend across the divide between the headwaters of the Kuzitrin and Koyuk rivers and down the Koyuk Valley. Similar lavas were described in the Koyuk Valley by Mendenhall.[a] In the Noxapaga River many fragments of basalt were found in the gravels on river bars.

At a point on the Noxapaga River 2 miles above Noxapaga these lavas extend across the river, and their relation to the other rock was seen in a bluff above the river. Here the Pleistocene gravels filling the Noxapaga Valley rest on the upturned edges of the schists. The basalts lie upon these gravels, and near the contact the gravels are cemented by indurated clay. In the upper part of this gravel a few pebbles derived from basalt were found, mixed with quartz pebbles derived from the schist. This lava flow probably occurred in Pleistocene time, while the upper gravel plain of the Kuzitrin Basin was being formed. In the Koyuk Valley Mendenhall found evidence that the basalt is of Pleistocene or late Pliocene time.[b] The evidence obtained in the Kuzitrin Basin indicates a similar age for the basalts found there.

These basalts show phases from gray to black. They are more often vesicular than compact, the vesicles unfilled. Under the microscope they show large olivine phenocrysts and smaller phenocrysts of feldspar, probably labradorite, set in an almost opaque groundmass.

## DYNAMIC HISTORY.

The dynamic history of the province is complex, and, in spite of the two seasons of field work, still presents many unsolved problems. In the southern part

[a] Reconnaissances in the Cape Nome and Norton Bay Regions, Alaska, in 1900, p. 206.
[b] Idem, p. 207.

of the peninsula[a] four distinct periods of dynamic activity were recognized, and some evidence was obtained of a fifth, which antedated all the others. The facts which suggested this oldest period of disturbance were those which indicate a deformation of the Kuzitrin series previous to the deposition of the Nome series. This unconformity was, however, not definitely established by independent evidence.

The record of the oldest of the four periods of revolution which were definitely recognized in the southern belt is found in the broad, often dome-like, folds which affected all the rocks up to and including the Nome series. The crustal movement resulting in this doming was accompanied by large injections of greenstones, and it probably occurred in pre-Silurian time. The next disturbance was one which rendered these greenstones schistose, and locally produced considerable shearing and jointing. Its effects are exhibited by local deformation and metamorphism in the Nome series, and its date was probably Mesozoic. The third crustal movement was more widespread in its effect, and was accompanied by the intrusion of large granite masses along the axes of the Kigluaik, Bendeleben, and Darby mountains. The age of this dynamic revolution can be definitely assigned to the late Mesozoic or pre-Tertiary. The evidence of a still later epoch of crustal movement was found in the sheared and jointed character of some of these granite masses.

The investigations of the past season in a general way corroborate this statement of the dynamic history of the province. More definite evidence of the unconformable relation of the basal member of the Nome series to the Kuzitrin series was obtained (see p. 17). The Kuzitrin series, as has been shown, suffered some metamorphism previous to the deposition of the Port Clarence limestone, which is the lower member of the Nome series. As the Port Clarence limestone is of Lower Silurian age, this crustal movement can be definitely assigned to the pre-Silurian.

The first well-established epoch of dynamic activity in the Nome region proper was the period of the intrusion of the greenstones, and this is also recognized in the northern province. The writer is, however, unable to present any evidence of the presence of dome structures similar to those which were described by Brooks[b] and assigned to this period.

The next epoch of disturbance which was recognized in the southern part of the province was the post-Nome revolution. In the northern region this epoch has also been recognized, but was proved to be rather local in its effect. In the York Mountains the beds belonging to the older member of the Nome series were found to be but little affected by this movement, while in the eastern part of the province the upper member of the same series is sharply folded and con-

[a] Reconnaissances in the Cape Nome and Norton Bay Regions, Alaska, in 1900, p. 39.
[b] Idem, p. 31.

GRANITE OUTCROPS NEAR HOT SPRINGS.

siderably metamorphosed. This is in accordance with the fact, pointed out by Brooks,[a] that the disturbances were of a local character. As in the southern belt, both the sediments and the igneous rocks were rendered schistose by this movement. This disturbance was provisionally assigned to the Mesozoic, and is shown by the work of the past season to be at least post-Devonian.

The third period recognized by Brooks has been the last one of extensive deformation. Deformation and alteration were accompanied by the intrusion of the granites of the Kigluaik and Bendeleben mountains. In the southern province this disturbance is shown by structural lines which run parallel to the axes of the mountains and have a general east-west trend. In the northern belt no large intrusions of granite occur, but there are structural lines running east and west, which may have been produced by this crustal movement, as noted more especially in the York Mountains. The evidence, briefly summarized, is as follows: In the York Mountains, where the bed rock is chiefly the Port Clarence limestone, broad, open folds were observed whose axes run nearly east and west. These are transverse to the lines of more intense disturbance in the eastern part of the belt. As is shown by the character of the rocks in the eastern belt, the western belt must have remained practically undisturbed during the early Mesozoic evolution which has been described. These in the York Mountains must therefore be of a later date than the north-south structures, and are here provisionally correlated with the epoch during which, in the southern part of the peninsula, the Kigluaik and Bendeleben mountains were uplifted.

No evidence of the fourth dynamic evolution described by Brooks was obtained by the writer, though it may exist. The extrusion of the lavas which have been assigned to the Pleistocene is the latest evidence of dynamic activity.

We have thus four definite periods of crustal movements, with accompanying injections, in the northern province. The first, which was probably regional, occurred in pre-Silurian times. The second was a period of intrusion, and can be provisionally assigned to the close of the Paleozoic, or the beginning of the Mesozoic. The third was a period of folding, which was rather local in its effect. The last was an epoch of extensive lavas, which, though rather widespread, was not great in the amount of material which was ejected.[b]

Since the injection of the granites and the uplift of the Kigluaik Mountains, which is assigned to the Mesozoic era, the northern portion of the peninsula has been base-leveled and uplifted and in the uplift has suffered more or less deformation. These features are described in some detail under the heading "Physiography."

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[a] Reconnaissances in the Cape Nome and Norton Bay Regions, Alaska, in 1900, p. 35.

[b] Mr. Henry S. Washington has recently described some effusive rocks from adjacent portions of the Siberian coast. See Am. Jour. Sci., 4th series, Vol. XIII, pp. 175–184.

## PHYSIOGRAPHY.

### INTRODUCTION.

A general statement with regard to shore line, drainage, and relief of the region under discussion has been given in the chapter on geography. A general discussion of the physiography of the Seward Peninsula, by Alfred H. Brooks, is also to be found in Reconnaissances in the Cape Nome and Norton Bay Regions, Alaska, 1900, pages 48–64 and pages 163–198. Mr. Brooks[a] has called attention to the fact that the Seward Peninsula may be divided, by a line from Cape Espenberg to Rocky Point, into two regions, of which the eastern has been depressed and the western uplifted. The region under discussion is a part of this uplifted portion. In the northern part of the peninsula many new facts bearing on physiographic development were collected. However, owing to the hasty nature of the work and the small scale of the map, and in view also of the fact that further exploration in an adjacent region is contemplated at an early date, the writer will only attempt to describe in a preliminary way some of the more important topographic features, and to suggest their possible history.

The northern portion of the Seward Peninsula is characterized by broad lowland plains surrounding a central upland. These lowlands are built up of silts, sands, and gravels derived from the upland, and deposited in shallow waters, probably both marine and lacustrine, which surrounded it. The lowlands to the southeast occupy inland basins extending parallel with the axes of the Bendeleben and Kigluaik mountains, which rise abruptly from their southern edge.

The relief of the upland is considerable, but its summits are flattened at elevations varying from 1,600 to 2,900 feet in different parts of the region. Between the summit level and the lowland plain there is a series of broad benches surrounding the central mass, two of which are particularly prominent. The different plateau benches and plains represent distinct epochs of erosion, and in the case of the lower gravels have been quite generally deposited since its formation. The existence of these features is regarded as indicating repeated uplifts, which affected the whole region.

In the case of the latest uplift there is unmistakable evidence that the movement was of a differential nature. Similar differential movements have probably occurred in connection with older uplifts, but definite evidence of them is wanting. Although the general movement has been one of uplift there is also evidence of local depressions of minor importance during the latest period. The four epochs of erosion indicated will be discussed further under the headings Nuluk Plateau, Kugruk Plateau, York Plateau, and Lowland plains.

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[a] Op. cit., p. 56.

mountain rises abruptly. Westward, along the north face of the York Mountains, it is represented by well-marked benches and the flat tops of a few isolated buttes. In the region west of the York Mountains the isolated buttes are flat-topped at 1,000 to 1,200 feet, and Cape Mountain has a well-marked bench at 1,200 feet. South of the Agiapuk River this platform, on which Mukacharni Mountain stands, is correlated with this plateau. In the eastern area, where this plateau is best developed, it is dotted over with scattering residuary buttes and mountains, of which Midnight, Baldy, and Harris mountains are types. The system of buttes and ridges extending southward from Kugruk Mountain rises above it, as do also Ear Mountain, Cape Mountain, and the York Mountains. It is impossible to state with certainty the nature of the erosion by which this feature was produced. In the vicinity of the Kugruk River the plateau surface is characterized by rounded hills and ridges, which often vary considerably in elevation, and rise gradually toward the bases of residual hills and mountains. The erosion of the Kugruk surface was probably subaerial, and it is proper to call the plateau a peneplain.

Since its formation this peneplain has suffered some deformation, the details of which are only imperfectly known. Southeast of Midnight Mountain, at latitude 64° 46′, the plateau has an elevation of 1,600 feet, while to the northward it appears to slope gradually down to the level of the Arctic coastal plain in a distance of 20 miles. To the southward it slopes toward the Kuzitrin Basin and has suffered erosion, so that it is only preserved in a few remnants. Coffee Dome, with an elevation of 1,000 feet, is such a remnant of the old plateau surface. In 1900 the writer, with Mr. Brooks, observed a broad bench with washed gravel on the west end of the Bendeleben Mountains. A further examination of the benches in this vicinity was made the past season. It seems probable that they are to be correlated with the Kugruk Plateau. These benches stand at an elevation of from 1,000 to 1,200 feet. This feature seems to indicate the formation by warping of a trough parallel with the Bendeleben Mountains since the development of the Kugruk Plateau surface.

### YORK PLATEAU.

The third important erosion epoch is represented by the York Plateau. It is well developed about the mass of the York Mountains, though its equivalents may be traced with a fair degree of certainty along the northern flank of the Kugruk upland to the Serpentine River, and along the southern flank to the Kuzitrin River. The breadth of this bench, where it has been observed, varies from 100 yards to 15 miles. It slopes from the mountains toward the sea both to north and south. Its general altitude varies from 100 to 700 feet above the sea. Notable variations which occur along a line parallel to the southern shore are undoubtedly traceable to warping.

The interval between the York and Kugruk plateaus is usually about 700 feet.

Between the York Mountains and Cape Prince of Wales the York Plateau is represented by a well-marked plateau surface at an elevation of from 500 to 700 feet. This was described by Brooks in 1900. It is a striking feature and has been noted by a number of early explorers. The top of the plateau is smooth and perfectly hard, affording excellent footing.[a] To the northward it slopes rather gradually to the level of the Arctic coastal plain, while at its southern margin it terminates rather abruptly in a steep slope or escarpment toward Bering Sea.

Eastward around the north side of the York Mountains the York Plateau is apparently continuous with an imperfect plain surface developed over the hilltops at an elevation of 300 to 500 feet above sea level. Around the north side of the York Mountains this plain extends into the mountains in a system of broad benches along the rivers which emerge from them. On the Nuluk River this feature is developed in a broad valley floor about 400 feet above the present stream bed. At this place the plain extends through the upland in a broad pass between the waters of the Nuluk and Agiapuk rivers at about 500 feet elevation.

Surrounding Ear Mountain there is an extensive upland composed of rounded ridges which attain an elevation of 500 to 600 feet, and which seem to be continuous with the York Plateau as developed farther west. From these levels there is a gradual rise of the land toward Ear Mountain, at whose base is a well-marked platform having an elevation of 1,000 feet, from which the mountain rises abruptly for 1,300 feet.

From Ear Mountain to the Serpentine River this bench was not traced, and the topographic map affords no evidence of its existence. However, on Spring Creek, a tributary of the Serpentine River, benches at about 600 feet were observed, which may be tentatively correlated with this plateau.

South of the York Mountains a broad marine bench from 1 to 3 miles wide is cut on the Port Clarence limestones, of which the mountains are composed. This has been elevated from 100 to 600 feet above the sea and is bounded on the south side by a steep escarpment to the Port Clarence coastal plain or by a cliff to the sea. On the north it is bounded by the abrupt slopes of the York Mountains. The surface of this bench is an almost perfect plain swept bare of gravel or other detrital material, but is covered in many places with yellow clay derived from the solution of the limestone. A study of the topographic map shows with certainty that this bench is a continuation of the York Plateau above described.

Between the California and the Agiapuk there is a broad plateau surface having an elevation of about 500 feet. This plain extends up the Agiapuk River as a broad bench and is continuous over the divide with the benches along the

[a] Reconnaissances in the Cape Nome and Norton Bay Regions, Alaska, in 1900, p. 132.

Nuluk River, which, as has been shown, are connected around the northern side of the York Mountains with the York Plateau. Eastward from the great bend of the Agiapuk River this plateau has not been traced with certainty. The plateau between Grantley Harbor and Imuruk Basin, in which Tuksuk Channel is cut to a depth of about 200 feet, and the plateaus and benches along the Kuzitrin River between the Imuruk and Kuzitrin basins are tentatively correlated with it.

The York Plateau, since its elevation, has been dissected to a base-level by the larger streams which cut across it. The smaller of these streams flow in sharply cut new V-shaped canyons, while the larger streams flow in comparatively broad valleys. An example of the larger valley is shown in the Anikovik River, which has a width of several miles (see topographic map), while its smaller tributaries, such as Deer Creek and Buhner Creek, are still in sharply cut canyons. In the northern and eastern extensions of the York Plateau the valleys are broader and generally appear to be older. The sharply cut V-shaped valleys are only seen near the foothills of the mountains. Along the northern margin of the plateau the gravels of the Arctic coastal plain extend up the valleys, making it often difficult to draw the boundary between the lowland region and the upland.

In the eastern extension of the York Plateau, south of the York Mountains, the smaller streams flow in very abrupt canyons, with almost perpendicular walls, which interrupt the continuity of the plain, and are discovered only when the traveler stands on their immediate edge. However, Rapid River, the largest stream which crosses this bench, has a broad valley quite similar to that of the Anikovik River. The California River and Tuksuk Channel both occupy sharply cut canyons in plateaus which have been correlated with the York Plateau.

On that portion of the York Plateau which has been called the Cape York bench the plain surface appears to be perfectly developed, but elsewhere there are a number of residual hills, usually at places where the slates are intruded by stocks or sills of igneous rock. Cape Mountain, the largest of these hills, is of this type. It rises in a sharp peak 2,000 feet above the plateau level. It is composed of harder rocks of an older series than the slates to the eastward, raised up and intruded by a large mass of granite. Conical Hill, rising about 1,000 feet above the plain, is composed of slates similar to those of the surrounding plateau region. Other smaller buttes have been found, when examined, to be composed, in part at least, of greenstone, which seems to be an altered gabbro. On the northeastern extension of this plain there are a few residual hills near the southern margin which were not examined in detail.

Concerning the manner in which the York Plateau was produced it may be said that the Cape York bench, which is an almost perfect plain, was undoubtedly

*A*. SOUTH SIDE OF YORK MOUNTAIN AND BEACH.

*B*. CAPE MOUNTAIN, FROM YORK.

produced principally by marine erosion. It was cut in the southern side of the York Mountains by wave action. The main portion of the York Plateau has been regarded by Brooks[a] as of similar origin. Some slight irregularities on the surface of this plateau, which are apparent on more detailed topographic examination of the region, would seem to throw some doubt on this statement. It seems probable that this is in part of subaërial origin. In the northeastern extension of the plateau these irregularities increase, and it seems probable that the plain here was to a greater extent produced by subaërial agencies.

In its elevation to the present level, this plateau has suffered marked deformation, and the proof of differential movement which is afforded has been sufficient to throw doubt upon correlations in the case of widely separated plain surfaces within the region. But it has also confirmed the opinion that many of the inland basins of the region owe their origin to such warping. The deformation is most strikingly shown in the marine bench south of the York Mountains, above referred to as the Cape York bench. This bench, which must have been horizontal at the time of its formation, has an elevation of 200 feet at Don River, while 12 miles to the westward the same plain has an elevation of 600 feet. Near the Kanauguk River the York Plateau has an elevation of 800 feet, while at the east base of Cape Mountain the elevation is below 500 feet. The plateau between the California and Agiapuk rivers has an elevation of 500 feet. This plain is located about 10 miles east of the depressed portion of the York Plateau, near the Don River. The benches and plateaus about Imuruk Basin, which have also been correlated with this plateau, have elevations of from 200 to 300 feet.

If these correlations are correct, the York Plateau along its southern edge shows the following variations in level, due to warping: Near Cape Prince of Wales its elevation is 500 feet; 8 miles eastward, near the Kanauguk River, its elevation is 700 feet; 20 miles eastward, at the Don River, it stands at 200 feet; 10 miles eastward, at the California River, it stands at 500, and 20 miles farther east, at Tuksuk Channel, it stands at 200 feet. It has been noted that the plateau surface seems to slope to sea level and merge with the coastal plain. It is impossible to tell, in the present state of information, to what extent this may be due to deformation. The great accumulation of gravel in this region was probably largely derived from the region of the York Plateau, and the fluviatile agencies have here acted more strongly and for a longer time, making the valleys wider and rounding off the upland between them.

[a] Reconnaissances in the Cape Nome and Norton Bay Regions, Alaska, in 1900, p. 59.

### LOWLAND PLAINS.

The last epoch of erosion is represented by the extensive lowland plains which surround the upland mass. They comprise coastal and valley plains, and in general are covered by unconsolidated Pleistocene deposits. In each case these deposits are probably underlain by even rock floors, representing a period of erosion which preceded subsidence and deposition. It is suggested that in the southeastern part, previous to this deposition, wide valleys were converted into basins by warping. The lowland areas have been already partly described under the heading "Surficial deposits." They are the Arctic and Port Clarence coastal plains and the lowland surrounding Imuruk Basin and occupying the broad valleys of the Agiapuk and Kuzitrin rivers, tributary to that basin.

The Arctic coastal plain extends from Cape Prince of Wales to Cape Espenberg. At Cape Prince of Wales it is not over 5 miles wide, but about Shishmaref Inlet it extends inland for 30 miles to the base of gently sloping hills which rise up to the Kugruk Plateau. To the eastward it appears to cover a large part of the peninsula between Shishmaref Inlet and Goodhope Bay. At its southern margin it is probably nowhere above 200 feet in elevation. The rivers and creeks which flow across it usually have intrenched their channels into the frozen deposits of the plain, sometimes exposing a face of gravel 20 feet high. In being elevated to its present position, this tract is not known to have suffered warping. All irregularities seen by the writer may be attributed to irregular deposition.

The Port Clarence coastal plain is a small gravel-covered plain north of Port Clarence. It has a maximum width of 5 miles, but is usually much narrower. The gravels thin out toward the foothills, where in river sections they are seen to rest on the truncated edges of the limestone bed rock. Westward this plain extends in a narrow strip toward Cape York, where it is interrupted. The plain on which the village of York is built is regarded as belonging to the same erosion period as this plain. During the uplift this plain has suffered some slight deformation. At the mouth of the Don River the plain is scarcely above sea level, while at the Teller Mission its elevation is about 20 feet. North of the entrance to Grantley Harbor it appears to dip down and pass below sea level.

### VALLEY LOWLANDS.

These are the low-lying plains which surround the Imuruk Basin and occupy the Agiapuk and Kuzitrin valleys.[a] They have a general similarity, and are probably to be accounted for by similar causes. The Imuruk lowland is partly occu ie by the waters of Imuruk Bay. North of the bay the lowland has a width of about 6 miles, but extends farther northward in embayments in the surrounding hills. It is

[a] Reconnaissances in Cape Nome and Norton Bay Regions, Alaska, in 1900, pp. 51 and 62.

in many places there are small isolated gravel buttes and hills which are remnants of the same higher plain that is shown in the benches.[a] Whether this upper plain represents a higher water level over the whole basin or is simply a part of the old plain raised up differentially, can not be determined from the evidence in hand.

The basins in which these lowlands occur, it is believed, were first formed as broad erosion valleys during the epoch represented by the York Plateau. In the process of uplift, deformation occurred, forming inland basins in which the lowlands were built up of silts and gravels and the uplifted portions of the valley floor were dissected and are now represented by the 200-foot bench along the Tuksuk and the flat-topped hills around the Kuzitrin Canyon. Since the formation of the lowland plain, a slight subsidence has allowed the sea to invade the Imuruk Basin and slight deformation has raised up portions of the lowland gravels, subjecting them to erosion and forming the gravel mesas and benches above described.

### DRAINAGE.

In the upland portions of the region, the rivers flow in deep-cut valleys, while in the lowland portions they meander in shallow valleys trenched to near sea level. In general in the upland portions no readjustment of drainage can be recognized. The present stream courses are inherited from previous physiographic conditions. The few minor changes of drainage which have been noted can here be neglected.

The Agiapuk River, at the place of its emergence upon the York Plateau from the Nuluk upland, presents the most interesting case of deflected drainage observed. Its deflection eastward toward the Agiapuk lowland, through which it flows to Imuruk Basin, is believed by the writer to be due to the warping of the plateau surface while it was yet a lowland. Whether it has ever had an outlet directly southward to Port Clarence can not be certainly determined. If it did have such an outlet, it was perhaps obstructed by the lava flows which occurred in the vicinity, probably near the time of the uplift and warping.

The California River, having a steeper gradient and a shorter course to sea level, has cut a steep canyon in this plateau surface and will probably ultimately capture the upper part of this river and restore it to its former course to the sea.

### SUMMARY.

From the above facts and discussion the following conclusions are drawn. There have been four extensive periods of erosion in this region, separated by periods of elevation. These periods of erosion are evidenced by systems of plateaus, benches, and plains named as follows in the order of their formation: The Nuluk Plateau, the Kugruk Plateau, the York Plateau, and the Lowland

[a] See also "Surficial deposits," p. 24 et seq., and economic description of Quartz Creek and Bowlder Creek, pp. 62, 66.

especially the Kugruk, Kuzitrin, and Agiapuk rivers. A little gold has also been found at York.

The source of the gold is undoubtedly in the bed rock, not far distant from the placers where it is found. Though no large veins of commercial importance have been found, there are many small veins and stringers, which are often more or less mineralized, and from these the gold has been derived.

Such mineralization as the rocks of the region exhibit can only occur in areas of deformation where the rocks have been jointed and fractured. In the region under discussion the rocks of the Kuzitrin series and of the Kugruk group present conditions favorable for mineralization, and a comparison of the geologic and economic maps will show that gold-producing areas are in a general way identical with the area occupied by these two groups.

The bed rock of most of the auriferous creeks is made up of the Kugruk beds, but there are some gold-bearing creeks whose courses cut the Kuzitrin series. The inference is that the erosion of the Kugruk rocks contributed most of the gold which is now found in the placers. In any event it can be definitely stated that the Port Clarence limestone is not gold bearing, and it will be a useless waste of time for prospectors to search for placers in the region occupied by these rocks. The placers which have thus far been developed are confined entirely to the stream beds of the smaller creeks, though the larger rivers carry fine gold, which may some time be worked to a profit. There is also a possibility that gold values may be found in some of the gravel terraces, which might be worked by hydraulic methods.

## DESCRIPTIONS OF LOCALITIES.

### INTRODUCTION.

Since the region promises to be of some importance in placer mining, and since much of it has been prospected, it has been thought best to add the following detailed descriptions of those creeks which were visited by the party. The writer will also include some accounts of adjacent regions, about which reliable information was obtained. It is hoped that these notes, incomplete as they are, will throw some light on the economic possibilities of this region. The placer tin deposits of York will also be briefly considered. The regions described coincide in a general way with the various recording districts, but since the boundaries of the districts are often indefinitely located and are subject to frequent change, no attempt has been made to follow them closely.

### GRANTLEY HARBOR REGION.

Under this heading an area will be considered which is tributary to and north of Grantley Harbor. In 1900, colors of gold were found in several creeks

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which flow into the harbor from the north, but no mining proper was done.[a] The Bluestone region, which was described in the report cited, and lies to the south of Grantley Harbor, in 1900 produced considerable gold, but during 1901 hardly realized the expectations. The Bluestone Basin lies outside of the region considered in this report.

More or less successful mining has been done on Sunset and Igloo creeks, flowing into Grantley Harbor, and Allene Creek, flowing into the Agiapuk. When the writer visited Sunset Creek on July 14, sluice boxes had just been set up on one claim. Assessment work, represented by drain ditches, crosscuts, etc., had been done at several places, but little could be learned regarding the probable value of the creek for mining purposes. Sunset Creek is about 5 miles in length. In its upper part it occupies a rather deep canyon, while in the lower 2 miles of its course it is only slightly incised in the rolling, moss-covered lowland which borders Grantley Harbor. The bed rock, where it has been seen, consists of fine-grained chloritic mica-schists and very highly altered greenstones, composed almost wholly of secondary minerals, but probably representing basic intrusions in the schists. The schists contain many small veins of quartz. About 4 miles from the coast the creek forks, the larger branch rising on the east side of Mukacharni Mountain, while the west fork rises west of that mountain. This mountain is composed of unaltered basalt, which extends practically to the forks of the creek. At the head of the west fork calcareous schists and limestones, which probably overlie the mica-schists, were found. The relation of these mica-schists and limestones to the Port Clarence limestones, which are well represented a few miles west, was not determined, although all the evidence obtained seems to indicate that they underlie them. If this is true, these rocks should be correlated with the Kuzitrin slates. At the forks of the creek, where sluicing had just begun at the time of the writer's visit, there was still a great deal of snow in the creek bed and the ground was still frozen to within a few inches of the surface. No exposure of bed rock at this place was seen. It was reported, however, by the miners, that prospect holes made the year before showed 4 feet of gravel carrying pay above a yellow clay bed rock.

Allene Creek heads a few miles southeast of Mukacharni Mountain, about 5 miles from Port Clarence, and flows northward to the Agiapuk River. The creek was visited by Mr. Witherspoon late in September. At the time of his visit one claim only was in operation. All the other claims were shut down for the season, although some mining had been done on several of the claims. The pay dirt was confined to the creek bed and rested on a clay foundation, below which the true bed rock had not been reached. About 3 miles down the creek a prospect hole is reported to have been sunk 65 feet without reaching bed rock. This shaft showed

[a] Reconnaissances in the Cape Nome and Norton Bay Regions, Alaska, in 1900, p. 126.

gravel at the top, below which there was blue clay containing bark and driftwood. The gold in Allene Creek is bright and flaky, not much waterworn. One small nugget was found during the season. The bed rock, consisting of mica-schist and greenstone, which was seen on the north shore of Grantley Harbor, probably extends northward at this place into the Agiapuk drainage, passing underneath the basalts of Mukacharni Mountain.

Sluicing was also done during the season on Igloo Creek, which enters Grantley Harbor a few miles east of Sunset Creek.

Bay Creek marks the eastern boundary of the Port Clarence limestones, which extend to the westward practically all the way to the Kanauguk River. None of the streams which enter Bering Sea from this limestone area are known to the writer to yield placer gold. On the north side of the Agiapuk the Port Clarence limestones, resembling those near Teller Mission, are well developed over a large area, and are probably not gold bearing. The gold-bearing gravels north of Grantley Harbor then will probably be found to be confined to the high land between Grantley Harbor and the Agiapuk, west of Bay Creek. The Agiapuk Valley itself is filled with Pleistocene clays and gravels, probably old lake-bed deposits, in which placer gold is probably not sufficiently concentrated to be of economic importance. The whole of this area is easily accessible from Grantley Harbor, and is entirely within a radius of 20 miles from Teller. On account of its location, mining can probably be done here at small expense.

Sunset Creek at its forks, 4 miles from the coast, carries sufficient water for sluicing, probably during the whole season. This is probably also true of Allene and Igloo creeks. If hydraulic mining should be attempted, water would probably have to be brought from the California River or the Agiapuk, which would require a long ditch.

### PORT CLARENCE AND YORK MOUNTAIN REGION.

Under this heading a region will be discussed which lies adjacent to and drains into Bering Sea, and embraces the southern drainage of the York Mountains and the streams tributary to Port Clarence from the north. With the exception of a few small areas the region as a whole is underlain by the Port Clarence limestone, which has never been found to be gold bearing. The more important streams which have received attention at the hands of prospectors are Mission Creek, and the California, Don, Lost, and Rapid rivers, besides a number of smaller streams whose names were not learned. Of these, as far as known, one of the forks of the Don River alone yielded colors of gold.

About 5 miles from its mouth the Don River forks, the eastern fork being known as Tozier Creek. This creek flows along the western base of a mountain composed of dark slates of the Kuzitrin series. These slates are cut by dikes

of white limestone, which probably belongs to the Kigluaik series. Cape Mountain is itself made up of an intrusive granite stock, which is much jointed. The Kuzitrin rocks are overlain to the east by the Port Clarence limestone, which makes up York Mountain. Near the west end of the two series there are some large intrusive masses of greenstone.

The bed rock of the Anikovik River consists of slates in which the original bedding is lost, and jointing and cleavage lead to the breaking up of the rock into pencils and rhombohedral forms.[a] These slates contain a number of massive greenstone bodies, which are clearly diabasic in their origin. There are also interbedded some smaller schistose, greenstone sills, whose origin could not be determined. The mineralized portions of these slates were found to carry some gold, which is disseminated in quartz belts. Slates of this type were found extending northward along Grouse Creek and the Mint River to within a few miles of the lagoon, where they pass under the heavy gravel deposits which border the Arctic Ocean.

Buck Creek heads in Conical Hill, a sharp peak rising about 1,000 feet above the general level of the York Plateau, and is composed of slates which do not differ essentially from the slates of the surrounding country. A number of quartz veins, much decomposed and stained with iron, were seen in the slates at its base on the head of Buck Creek. An assay of a sample of this quartz, however, showed no trace of gold.

The Yankee River, a large tributary of the Mint River, heads near Brooks Mountain, the highest of the York group. This mountain is composed, in part at least, of slates similar to those at York, and in part of highly altered crystallized limestones, cut by granite and porphyry dikes. The mountain is almost wholly surrounded by Port Clarence limestones, which form hills on both sides of Mint River Valley several miles below the head of the river. The river occupies a broad, gravel-filled valley, in which there are no exposures of bed rock until, near the junction with the Mint River, the Kuzitrin slates are again exposed. The western branch of the Pinguk River, known as the York River, also heads in the slates of Brooks Mountain, and has cut down to the slates through nearly all its length until it enters the gravel-covered area near the Arctic Ocean.

*Gold.* The discoveries of more promising deposits in other parts of the peninsula had drawn away many of the prospectors whom Brooks found at York in 1900, and the backwardness of the season had delayed mining operations. In the whole district sluicing was in progress on only one claim. The entire district during the summer of 1901 probably produced less than $250 in gold. Several creeks flowing into the Arctic Ocean, which were not visited by Brooks in 1900, were found to carry colors of gold, but no sluicing was done.

[a] See also Brooks, A. H., Cape Nome and Norton Bay Regions, Alaska, p. 288, p. 255.

Grouse Creek, a tributary of the Mint River, is the most important stream flowing northward in the district. This creek is trenched in the plateau surface to a depth of from 100 to 300 feet, but for a great part of its course flows over gravel bars which occupy its bed, and at the present time the creek is broadening rather than deepening its valley. The eastern tributaries of Grouse Creek generally head in the York Mountains, and are largely filled with gravels composed of limestone, with some greenstone, the latter derived from the intrusives in slates near the base of the mountains. The western tributaries of Grouse Creek flow wholly within the slates, and offer more inducement to the prospector. Colors of gold have been found in Buck and Gold creeks, and prospectors were doing assessment work on the former at the time of our visit. A drain ditch 100 feet long had been cut near the mouth of the creek, and other developments were being made on some of the tributaries. In this ditch good prospects had been found. The gold was in rounded grains identical in character to the gold of the Anikovik River and Buhner Creek, which flow southward in the region. Well-rounded fragments of magnetite were found associated with the gold.

*Tin.*—During his examination of the York region Brooks's attention was called to stream tin[a] (cassiterite), which the miners had found in their sluice boxes but had not identified. This mineral was associated with garnets, magnetite, gold, and other heavy minerals in the sluice boxes. The source of the tin placer he was not able to determine, but believed that it was in the bed rock of the immediate vicinity of the placers. At the time of the writer's visit to this district mining operations had scarcely begun. There were, however, a number of prospectors who had only learned a few days before, from a bulletin sent in by Mr. Brooks, that the heavy mineral found in the sluice boxes was of possible economic value. Considerable prospecting for tin was done after this time, the details of which are not definitely known. It is reported that stream tin has been found by prospectors in nearly all the streams northeast from York for a distance of about 20 miles. The streams mentioned as carrying placer tin are the Anikovik River and all of its tributaries, the Kanauguk River, Baituk Creek, Kinzuk Creek, and Lagoon Creek, flowing into Bering Sea, and Grouse, Buck, Yankee, Mint, and York creeks, flowing into the Arctic Ocean. The York River, the western branch of the Pinguk, is said to be very rich in placer tin.[b] Gravel deposits, yielding from an ounce to a pound of tin to the pan, are reported to have been found. Pebbles of magnetite, worn smooth and having a luster resembling that of the tin, occur associated with and are often not easily distinguished from the darker forms of the cassiterite. This iron, being quite generally distributed through the placers

[a] Reconnaissances in the Cape Nome and Norton Bay Regions, Alaska, in 1900, p. 136; and An occurrence of stream tin in the York region, Alaska: Mineral Resources U. S. 1900, pp. 267–270.

[b] For this information the writer is indebted to T. B. Fish, of York.

of the region, may have been in some instances mistaken for cassiterite by the prospectors.

Tin veins, where found in other parts of the world, are usually associated with intrusions of granite or other acid igneous rocks. However, in Cornwall they are sometimes found in the slates adjacent to the granite. Wherever found the wall rocks are altered by mineralizing solutions, and are often impregnated with cassiterite. Where such veins occur in granite the important ore bodies are often found to consist of this altered wall rock, the feldspar of the granite being replaced by cassiterite.[a]

No acid eruptive rocks have yet been found within the drainage area of the Anikovik River. There are large intrusive masses of greenstone, which are probably gabbros, at the head of this river and also on some of its eastern tributaries. Sills of schistose greenstone, whose origin is obscure, but which are probably altered basic intrusives, occur distributed through the slates of the York region. The stream tin may be associated in the bed rock with these basic intrusives, though such an occurrence would be unusual. Tin-bearing veins of a type similar to ordinary silver and copper-bearing veins may occur in the slates of the York district, and so account for the distribution of the placer tin.

The region about York in which the Anikovik River and other tin-bearing streams are located has, in recent geologic time, been reduced to a plain, possibly in part by wave action and in part by subærial erosion.[b] At this time a considerable thickness of rock strata was undoubtedly removed by erosive agencies, and the heavier constituents of these rock masses must have been more or less concentrated upon the plain surface. Subsequent to this base-leveling the York plain has been elevated to a plateau, which has been dissected by the creeks and rivers of the region. That the elevation of this plateau is an occurrence of comparatively recent geologic time is shown by the fact that the smaller creeks flow in sharply cut V-shaped canyons, and have scarcely begun to broaden their valleys. As these valleys and canyons are developed, the heavier materials of the surface are naturally reconcentrated in them. If during the base-leveling period the heavier concentrates of the erosive agencies were transported to any extent from their original sources, and if they are again concentrated in subsequent creek beds, they may be found removed some distance from their original sources. It is possible that the rocks from which they came may in some instances have been wholly removed, leaving no evidence in the present bed rock to show what they may have been.

Waterworn pebbles and bowlders of gabbroic greenstone of the type which forms large masses about the head of the Anikovik River are common in the

[a] Genesis of ore-deposits, by F. Posepny: Am. Inst. Min. Eng., 1902, p. 139.
[b] Reconnaissances in the Cape Nome and Norton Bay Regions, Alaska, in 1900, p. 132.

beds of the Anikovik River and Grouse Creek. These bowlders are frequent along Buhner Creek, where the tin was first found. No rock of this character has been found in the bed rock within the Buhner Creek Basin, or indeed within 5 miles of Buhner Creek. There is no evidence that these bowlders were transported to their present place otherwise than by being rolled along with currents of water. The possibility of their being floated on shore ice at some time of submergence must be considered. The wide distribution of the stream tin in this region, together with the fact that pebbles and bowlders of known origin have been widely distributed independently of the present drainage, suggest at least that the original source of the stream tin may be some distance from the present deposits, and is not necessarily to be found within the present drainage of the streams where it occurs. Acid igneous intrusions, such as cassiterite veins, are usually associated with, are found in Cape Mountain and Brooks Mountain. The slates of Brooks Mountain have suffered great metamorphism. The York River, which is reported to be very rich in tin, heads in this mountain and carries granite pebbles and bowlders, which suggests that the tin had its origin near the granite contact. The wide distribution of this mineral in the creeks of the York district justifies the belief that the veins from which it is derived will yet be discovered.

## ARCTIC REGION.

The Arctic recording district includes the drainage of the Arctic Ocean between the Mint River and Shishmaref Inlet. The old recording office of the district, which was located a few miles west of Ear Mountain, at the junction of Tuttle Creek with the Kugruk River, has been abandoned. The general area included in the Arctic district will, however, be described in this report under the heading "Arctic region." It includes a number of rivers and creeks which flow northwestward into the lagoons bordering the Arctic Ocean. The three largest of these rivers are designated on the map by the native names, Pinguk, Nuluk, and Kugruk.[a] All of these rivers have received attention from prospectors, and during the early part of the season of 1901, at the time of our visit, a mining camp was located on Tuttle Creek, one of the tributaries of the Kugruk. So far as is known to the writer, however, no discoveries of valuable placer deposits were made. Adjacent to the shore is a belt of low-lying coastal plain which is dotted over with small lakes and underlain by thick layers of gravel, but in which no bed rock is exposed. Back of this coastal plain there is a gently rolling plateau standing 400 to 500 feet above the sea, and more or less dissected by streams and river valleys. This upland plain is the continuation of the York Plateau. It is terminated to the south by more abrupt slopes rising to higher hills.

[a] There are two other rivers of this name in the northern part of the Seward Peninsula.

*Pinguk River.*—This river flows into a lagoon about 30 miles northeast of Cape Prince of Wales, and has a serpentine course over the gravel of the coastal plain in its lower stretch. About 10 miles from the sea the river forks, the western fork being called the York River, the eastern being known as the McKillop River. The York River heads at the eastern end of Brooks Mountain, and flows northeastward to its junction with the McKillop River. In crossing the plateau above mentioned it occupies a valley from 200 to 300 feet deep. Along this valley slate bed rock is exposed through part of the distance, at least, and the stream gravels contain pebbles of slate derived from the Kuzitrin series as well as limestone derived from the Port Clarence limestones. It is reported that stream tin has been found in this river, with but little, if any, gold. No development work had been done on this river at the time of the writer's visit early in August.

McKillop River rises in the limestone hills which form the eastern extension of the York Mountains. Its valley is cut almost wholly in limestones of the Port Clarence formation, and it is not known to have yielded colors of gold.

*Nuluk River.*—This river enters the lagoon 40 miles northeast of Cape Prince of Wales. It heads in the high mountains made up of the Port Clarence limestone about 35 miles south of the Arctic Ocean. For 15 miles from its head the river occupies a canyon, varying from 100 to 1,000 feet in depth, cut in these Silurian limestones. Fossils of the same age as those north of Port Clarence were found about the head of the river. Northward along its course the character of the bed rock changes, and calcareous mica-schists are found. The Silurian limestones dip toward the schists, and near the contact with them are very highly folded. These schists are believed to overlie the limestones.

The coastal plain gravel extends inland farther along the Nuluk River than it does on the other rivers of this region. No colors of gold are known to have been found in the gravels of the Nuluk River or of its tributaries. The unaltered limestones through which it flows do not contain mineralized veins, and are not promising as sources of placer gold.

*Kugruk River.*[a]—This river enters the lagoon about 45 miles northeast of Cape Prince of Wales, and lies almost wholly within the coastal plain gravels and the York Plateau. Its source is about 25 miles from the sea, but it has a number of tributaries from the northeast side, which give it a comparatively large drainage area.

The bed rock about the river's head is limestone and calcareous schist, with some intrusive greenstones. The river and its tributaries have cut valleys from 200 to 400 feet deep in this bed rock. These limestones are probably in part Silurian,

[a] It should be noted that there are two other rivers of this name in the region.

but they are more highly crystalline than the Port Clarence limestone, and their exact relation to that formation was not determined.

The bed rock along the Kugruk River seems promising for placer gold. Many claims were found staked along it and its tributaries, although very few prospectors were seen in the region. It is not known to the writer that gold has been found along the river.

Tuttle Creek is a northern tributary of the Kugruk River, about 10 miles from the mouth. The creek heads on the north side of Ear Mountain, and has cut a rather narrow valley in the plateau which surrounds the mountain. During the summer of 1901 Tuttle Creek was the scene of a small excitement caused by reports brought out the year before. About 50 men visited the creek during the course of the summer. Colors of gold and small nuggets are reported to have been found in the gravels, but the creek was practically abandoned before the end of the season. Through much of its length the creek meanders over gravel flats with no bed-rock exposures, but about 5 miles from its head dark quartzite or slate bed rock outcrops. This quartzite extends to the head of the creek at Ear Mountain, contains large intrusions of granite, and is more or less metamorphosed by them. The stratigraphic relations of these slates could not be definitely determined. In lithologic character they resemble Kuzitrin rocks, and are regarded by the writer as belonging to that formation.

*Other streams.*—Between the Kugruk River and Shishmaref Inlet there are several small streams, none of which were visited by members of the Geological Survey party. It is not known that any of these have yielded colors of gold.

*Quartz veins.*—The dark slates in which the granite of Ear Mountain is intruded are often cut by small veins of quartz more or less mineralized. A specimen taken from a slide in the bank of Crosby Creek, about 3 miles south of Ear Mountain, consisted of glassy quartz and large crystals of pyrite. It was assayed by Dr. E. T. Allen, of the United States Geological Survey, and showed a trace of gold.

## SHISHMAREF REGION.

The Arctic drainage of the region lying east of the Arctic district will be considered under this heading. The name is taken from Shishmaref Inlet, which is the deepest embayment on the northern coast line of the peninsula. The region all lies in the Goodhope recording district, which also embraces a considerable area to the east, outside of the region surveyed by our party.

This district includes the drainage of Shishmaref Inlet and the western drainage of Goodhope Bay, together with the peninsula lying between them on which Devil Mountain is situated. As far as known to the writer no gold has been found in this district east of Shishmaref Inlet.

With the exception of Devil Mountain, the region between Shishmaref and Goodhope Bay is low and flat. It was not explored by members of the Geological Survey party, and little is definitely known of it. The surface, as viewed from Ear Mountain and Midnight Mountain, appears to be an erosion plain slightly elevated above sea level, above which rise a few low dome-shaped buttes. The topography of these buttes suggests that the bed rock is composed of schist and limestone. Devil Mountain rises about 600 feet above the general level, and is a ridge with a northwest trend, and has on its summit a number of jagged crags. Kotzebue, who named the mountain, compared its irregular crest to a ruined castle. These rocks are probably outcrops of granite similar to that of Ear Mountain.

The rivers flowing into Shishmaref Inlet have received considerable attention from prospectors. A recording office and Shishmaref post-office are located on Sarichef Island, at the northeastern entrance to Shishmaref Inlet. The writer was informed by Charles W. Mashburn, the deputy recorder of the district, that there is a good harbor for small coasting vessels at this place, and that the Serpentine, the largest river of the district, is navigable for small steamers for at least 20 miles inland. Kotzebue reported 8 fathoms of water at this entrance. Shishmaref Inlet is bordered by a wide coastal plain, made up of gravel, from the margin of which a dissected erosion plain slopes upward to an elevation of 500 to 1,000 feet. Ear Mountain, Kugruk Mountain, Midnight Mountain, and Devil Mountain, rising above this plateau, mark the limits of the Shishmaref drainage. The Serpentine and Arctic rivers are the two most important streams of the basin.

*Arctic River.*—The Arctic River rises south of Ear Mountain, has a length of about 25 miles, and flows into the west side of Shishmaref Inlet. Southeast of Ear Mountain the course of this river is in a broad basin containing a number of small lakes. Below this basin the river has cut a well-defined canyon. Viewed from the surrounding hills the basin appears to be an old lake bed. A broad, flat divide, which has what appears to be an abandoned river channel across it, separates this basin from the drainage of the Kugruk River of the Arctic region.

The bed rock is highly crystalline limestone and calcareous schists, with occasional highly altered greenstones. Veins and stringers of quartz are frequent. These limestones and calcareous schists were found within a short distance of the slates of Ear Mountain. If, as seems probable, they overlie these slates, they are to be correlated in part with the Port Clarence limestones. Their highly altered condition, however, in the absence of definite stratigraphic evidence, makes this correlation doubtful, and they have therefore been mapped with the more indefinite Kugruk group of schists and limestones.[a]

[a] See description of the Nome series, pp. 21-24.

Many of the tributaries of Arctic River have been staked, and colors of gold are reported to have been found. At the time of the writer's visit, in August, all of the prospectors had left the river.

*Serpentine River.*—This is the largest river of the district. Heading near Midnight Mountain, about 35 miles from Shishmaref Inlet, it flows into that inlet by a very sinuous course, from which character it receives its name. The river was first explored and named by Charles McLennan, who, with dog team and Eskimo assistants, made a trip into the region from Shishmaref Inlet in May, 1900. McLennan was probably the first white man to reach the hot springs on Spring Creek, a tributary of this river. He staked a number of claims along this creek, and prepared a map of the region, a copy of which was received in Washington in March, 1901. In September, 1901, the writer found a small settlement at the hot springs, but no trace of the claim stakes set up by McLennan the year before remained. A small garden had been made on some of the ground near one of the springs, and vegetables, consisting of lettuce and radishes, had been grown without difficulty.

The bed rock of the Serpentine River Basin above the coastal gravel belt consists of dark graphitic and feldspathic mica-schists, which form Midnight Mountain, and of crystalline limestones and mica-schists of the Kugruk group. The relations of the dark schists to the limestones were not determined, though they are regarded as belonging to the Kugruk series. In the vicinity of the hot springs these dark schists have been intruded by extensive granite masses, forming a large area of granite. This granite outcrops in needles and pinnacles, produced by weathering along a double set of joints.

Colors of gold are reported to have been found on a number of the tributaries of the middle fork of this river, and in September a number of miners were preparing to winter in the neighborhood, the principal settlement being at the hot springs. In the season of 1901 development work preparatory to mining was reported on Schlitz, Bella, and Bryan creeks. No gold in commercial quantities has yet been taken from any of these creeks, and owing to the limited amount of time at his disposal the writer was unable to visit them.

Two routes of travel are used by prospectors entering this region overland. The first is from Teller to the junction of the Agiapuk and American rivers, thence up the American River and Portage Creek to the divide, and around the north end of Kugruk Mountain. The second is from Nome or Teller by way of the Kugruk River and Macklin Creek. This creek heads within a short distance of the head of the Serpentine River. The first of these routes is used for travel with dog teams in the winter; the second is more generally traveled in summer.

Along Spring Creek for a distance of about half a mile there are hot sul-

to have been found in the tributaries which enter the Agiapuk from the north side. The unaltered and unmineralized character of the bed rock is not favorable for the occurrence of gold.

*American River.*—The American River is the eastern and larger fork of the Agiapuk. It joins the Agiapuk River in a broad, gravel-filled basin, and for 20 miles up is characterized by a wide flood plain and a meandering course. It receives a number of large tributaries from the east, which also have wide flood plains developed in their lower parts. The important tributaries are Portage Creek, Budd Creek, and Igloo Creek, while smaller tributaries are Burke, Gold Run, Dome, and Camp creeks. All of these tributaries have received some attention from prospectors. The river is easily navigable for small boats for several miles above the mouth of Portage Creek, and the region can also be easily reached by pack train from Teller.

During our brief stay in this region in the latter part of August no mining was being carried on, and but few prospectors were seen, although gold had been discovered in the region in September of the previous year, and a number of the streams[a] are known to be gold-bearing to some extent. Some assessment work, consisting of prospect holes and crosscut ditches, had been done earlier in the summer.

Above Portage Creek the American River has an east-west course for about 20 miles. This part of the river was not examined by the writer, and no discoveries of gold are known to have been made. The bed rock at the head of the river consists of the limestones of the Port Clarence formation. These limestones are little altered and are not mineralized to any extent, and are probably not productive of placer gold. At the mouth of Portage Creek, where this river was examined, the bed rock consists of calcareous mica-schists and limestones, which are more promising as a source of placer gold. The bed rock between these points is not known, although the topography suggests the extension of the Port Clarence limestones for some distance down the stream.

Portage Creek heads about 15 miles southwest of Shishmaref Inlet, and flows eastward for several miles in a canyon cut in the plateau which slopes down to that inlet. It then turns southward and flows in a comparatively deep valley for 10 miles, to its junction with the American River. Through the last 5 miles before entering the American River a broad flood plain is developed, within which the creek has a very sinuous course.

Along Portage Creek limestones and calcareous mica-schists, with occasional beds of graphitic schist, constitute the bed rock. Prospect holes and one crosscut ditch 100 feet long were seen, but no active mining was in progress.

[a] Reconnaissances in the Cape Nome and Norton Bay Regions, Alaska, in 1900, p. 125.

Budd Creek enters the American River from the east, about 6 miles below Portage Creek. It is 15 to 20 miles in length. About 3 miles from its mouth it receives a large tributary, Windy Creek, from the south side. About 10 miles above its mouth it forks, the two parts coming from the north and south, their direction being determined by the strike of the bed rocks.

The bed rock on Budd Creek is composed of crystalline limestones, calcareous mica-schists, and graphitic schists, usually striking in a north-south direction, and having dips varying from 0° to 70°. Kugruk Mountain, a few miles east of the forks of Budd Creek, is made up of quartz-mica-schist, which has been thrown up into an anticline. Below the forks the creek sinks, leaving its bed dry except in times of high water. After flowing underground for about 2 miles, the creek rises again in a number of springs. This sink occurs where a massive bed of limestone, dipping downstream at a small angle, cuts across the creek.

Windy Creek is tributary to Budd Creek from the south about 5 miles from its mouth. This creek is about 5 miles long and flows nearly north, parallel to the strike of the bed rock, which consists of more or less flaggy beds of limestone, between which there is a strata of graphitic schist that outcrops along nearly the whole length of the creek. Near the head of the creek its bed contains many bowlders of greenstone, which are derived from sills intruded in the limestone near its head. The valley of Windy Creek is broad and gravel filled. Along the sides of the valley, back from the creek bed, the gravel extends up the slopes, forming some well-marked gravel benches. A cut bank of the creek shows 6 feet of muck overlying 6 feet of gravel. Prospecting has not reached bed rock.

Along the upper parts of Budd Creek many claims have been staked, and assessment work, consisting of prospect pits and crosscut ditches, has been done in a number of places. Windy Creek is staked by one company for about 3 miles of its length. No prospectors were seen on Budd Creek or its tributaries, and no active mining has been done. This creek carries sufficient water for sluicing, except at the places where it sinks in passing over limestone. The same is true of Windy Creek, the large southern tributary.

Igloo Creek, also called on some maps Lewis Creek, enters the American River a few miles above its junction with the Agiapuk. This creek, like Budd Creek, flows west across the strike of the bed rock, which, as on Budd Creek, consists of limestones, calcareous and graphitic schists, with some intruded sills of greenstone, which are highly altered. Like Budd Creek, Igloo Creek sinks for about a mile of its course, probably in crossing the same bed of limestone that causes the sink on Budd Creek. In its lower course Igloo Creek meanders over a broad flood plain, from which the hills rise by very gentle slopes to the flat-topped upland.

Bendeleben mountains, and receives the drainage of the southern slopes of the Bendeleben Mountains.

The drainage basin of the Kuzitrin River has produced placer gold in a number of widely scattered localities, and its placers have been more or less exploited since the winter of 1899.[a] It was originally divided into two recording districts, the one known as the Kugruk district including the drainage of the Kugruk River below the mouth of that river, while the other, known as the Kuzitrin district, includes all the drainage of the Kuzitrin above the mouth of the Kugruk. From the head of Imuruk Basin to Marys Igloo, a distance of about 20 miles, the Kuzitrin River has no well-defined channel, but flows through a succession of small lakes or sloughs with many low islands between. This part of the river is called Kaviruk by the natives, and is, in fact, the delta portion of the Kuzitrin and Kruzgamepa rivers. Small steamers ascend the river to Marys Igloo, where is the first rapid and the limit of tidal influence. From Marys Igloo to the mouth of the Kugruk the river occupies a broad canyon cut in the upland. Through this canyon the river has long stretches of comparatively quiet water with small rapids between. The total fall in this distance does not exceed 100 feet. Above the mouth of the Kugruk a low, gravel-filled basin extends to the northeastward for a distance of 20 miles, with its longer axis parallel to the Bendeleben Mountains. In this basin the Kuzitrin River and its tributaries meander extensively. The southern tributaries of the Kuzitrin, before entering the lowland, emerge from deeply cut valleys in the Bendeleben Mountains, while the northern tributaries occupy canyons cut in a high plateau to the northward. The largest northern tributaries are the Kugruk and Noxapaga rivers.

The production of the whole drainage basin of the Kuzitrin River did not exceed $35,000 during the season of 1901. This amount is considerably less than the estimated product for 1900. The decrease in the production is due to the exhaustion, during the previous season, of certain shallow deposits of rich pay dirt and to the unusual shortness of the season of 1901, which did not permit the completion of systematic development work.

Along the Kuzitrin River below the mouth of the Kugruk the bed rock, wherever exposed, consists of the black slates and schists of the Kuzitrin series and the biotite-schists and granites of the Kigluaik series. No gold has been obtained in this part of the district.

Quartz Creek was visited by Brooks in 1900 and is described in detail in the report of that season's work.[b] The creek occupies a narrow valley, cut to a depth of 50 to 100 feet in a high gravel plain west of the Kugruk River.

[a] Reconnaissances in the Cape Nome and Norton Bay Regions, Alaska, in 1900, pp. 119–125.
[b] Idem, p. 121.

flows in a sharply cut canyon across the same high gravel plain. About 5 miles up, however, at the point where the wagon road from Lanes Landing to Quartz Creek crosses, the bed rock, consisting of a highly altered mica-schist, is probably near the surface. Some successful mining is said to have been done along this creek during the summer of 1901. This work had been suspended, however, at the time of the writer's visit in September.

Quartz Creek and Coffee Creek seem to carry considerable gold disseminated through a large amount of gravel. The deposits of gravel which can be worked successfully by the methods of mining now in use are probably of limited extent, so that more refined and economical methods will have to be ultimately adopted. Water for hydraulic purposes can probably be brought in a ditch from the head of Windy Creek, a distance not exceeding 10 miles. Brooks called attention to the probable occurrence of gold in gravels of the bench in which these creeks have incised their courses. These may possibly be worked by hydraulic methods. During ordinary seasons these creeks all carry sufficient water for mining by the methods now in use.

The Kugruk River is a large northern tributary of the Kuzitrin. It has a length, neglecting meanders and minor bends, of about 60 miles. Throughout the greater part of its course it occupies a canyon cut in a high plateau-like upland, which varies in elevation from 1,200 to 1,800 feet.

About 10 miles above its mouth the Kugruk River emerges upon the Kuzitrin lowland from its canyon. The course of this canyon is approximately north and south for 30 miles, and follows in a general way the strike of the bed rock. Below the mouth of Coarse Gold Creek the canyon is sharply cut, and no gravel benches or extensive gravel bars were observed in the creek bed. Above Coarse Gold Creek the valley broadens. At this place there are broad benches, about 20 feet above the river bed, cut on the upturned edges of the schists, and covered with several feet of gravel. Similar gravel benches occur occasionally as far as the mouth of Taylor Creek, above which point the creek bed was not examined in detail. At the mouth of Macklin Creek the Kugruk River turns sharply, and above this place it flows in an east-west direction from its source at the east base of Kugruk Mountain.

The bed rock along the Kugruk River is generally highly metamorphosed, consisting of mica-schists and calcareous schists, with large intrusions of greenstone. The greenstone is schistose, but has a porphyritic texture, the phenocrysts being hornblende, while the groundmass is made up essentially of epidote, hornblende, quartz, and chlorite, mostly secondary minerals.

Colors of gold are reported to have been found pretty generally distributed in the gravels along the Kugruk. Good prospects of placer gold and some mining are reported on Windy, Neva, North Fork, Coarse Gold, Henry, Taylor, and Macklin

creeks, tributaries of the Kugruk River. Many smaller tributaries have been staked to some extent, but of them the writer has no personal knowledge.

Windy Creek is a large tributary of the Kugruk River from the west. Its source is near that of Igloo Creek, which is tributary to the Agiapuk. Windy Creek flows across the strike of the bed rock in a deep canyon, cut in the Kugruk Plateau. The gravels seen at the mouth of this creek consist of greenstone, limestone, and mica-schist. The bed rock along the creek is reported to be a series of limestones and mica-schists.

Sluicing is reported to have been carried on for about two weeks on No. 14 on this creek, and developments made on a number of claims preparatory for work next season. Windy Creek carries sufficient water for ordinary mining purposes.

Neva Creek is a short tributary of the Kugruk River from the east side, about one-fourth of a mile above the mouth of Windy Creek. The bed rock at its mouth is gray mica-schist, highly metamorphosed. Sluicing was done in shallow gravels near the mouth of the creek during the summer. At the time of the writer's visit the camp was deserted, although the sluice boxes and canvas hose were still in position.

North Fork is a large tributary of the Kugruk River from the east, about 10 miles above Windy Creek. Harris Creek flows into North Fork about 4 miles from its mouth. The original discoveries of gold in the Kugruk region were made on Harris Creek, but during the season of 1900 it produced little gold. The writer was unable to visit the workings on this creek, but received the following information in regard to it from a prospector. Mining was in progress during September, 1901, on claims Nos. 4 to 10, inclusive. The creek cuts across the strike of the series of limestones and schists. At claim No. 11 the creek enters a limestone belt and sinks. Throughout nearly all the workings water for sluicing is insufficient on account of this sink. In all, 14 men were engaged in rocking and sluicing on Harris Creek during September. In these claims the bed rock consists of red and yellow clay, on which the pay gravel lies to a depth of from 3 inches to 4 or 5 feet. Above the sink Harris Creek carries an amount of water amply sufficient for mining purposes. North Fork and its tributaries generally have been staked and prospected to some extent. No mining has been done except on Harris Creek.

Coarse Gold Creek is a large tributary of the Kugruk River from the west side, about a mile above North Fork. It heads in the high divide between the Kugruk and Agiapuk drainages, and flows eastward, cutting across the strike of the schists and limestones. At the mouth of the creek the bed rock consists of highly altered mica-schists. Colors of gold have been found in the creek, but no mining has been done.

Henry Creek is tributary to the Kugruk River from the west, about 10 miles

above the mouth of the North Fork. It heads in the high divide south of Kugruk Mountain, and flows eastward in a deep canyon cut in the upland and across the strike of the schist and limestone bed rock. Good prospects of gold have been found on this creek, but no mining has been done. On the Kugruk River, immediately below the mouth of Henry Creek, a mining ditch has been dug and sluice boxes set up to work the gravels near the river. The mine was not in operation in September.

The Kugruk River forks about 35 miles from its mouth, the branches being of about equal size. The eastern fork is called Taylor Creek, while the western retains the name Kugruk River. Taylor Creek rises to the southeast of Midnight Mountain, and flows west to its junction with the Kugruk River. It occupies a valley about 800 feet deep, cut in the plateau on which Midnight Mountain stands. The bed rock at the mouth of Taylor Creek is a dark schist similar to that of Midnight Mountain, while immediately south of that mountain, at a point about 6 miles from the mouth of Taylor Creek, there are exposures of very much altered limestone. The creek probably cuts across the strike of a series of beds of schist and limestone. Colors of gold are known to have been found on this creek and some of its tributaries, but no mining has been attempted.

Macklin Creek is a tributary of the Kugruk River from the east side, about 6 miles above the mouth of Taylor Creek. It heads near the base of Midnight Mountain and flows westward about 6 miles to its junction with the Kugruk River. For several miles Macklin Creek flows parallel to Schlitz Creek, tributary to the Serpentine River, and a low pass between the two creeks suggests an old waterway. The creek occupies a rather broad valley cut in the upland. The bed rock, where it has been seen, consists of dark feldspathic, graphitic mica-schist, similar to that of Midnight Mountain. Promising prospects of gold were discovered on Macklin Creek in the summer of 1900. There are 29 claims on the creek, and considerable development work preparatory to mining was done during the summer of 1901, but by the middle of September no sluicing had been done. The thick vegetable growth of the hillsides also covers the creek bed, making a great deal of stripping necessary before mining can be begun. The pay gravel contains many angular fragments of graphitic schist. In the pay streak as high as 75 cents to the pan has been obtained, though the average is much less. Some sluicing was done on the creek after the time of the writer's visit. Though the exact results obtained are not known, they are reported to have been satisfactory and to justify a continuation of the work next year. Macklin Creek at the point where the present mines are located carries sufficient water for sluicing in all ordinary seasons.

About 15 miles northeast of the mouth of the Kugruk the Kuzitrin River forks, the northern fork being called the Noxapaga, while the eastern branch retains the

the mouth of Boulder Creek Turner Creek receives a number of tributaries, which together form a fan-shaped basin in the plateau surface. The larger forks of the creek head near Baldy Mountain. No mining has been done along Turner Creek, although good prospects of gold are reported to have been found and the whole creek is staked.

Boulder Creek occupies a straight, rather broad valley, which is deeply cut in the higher upland about the creek's head, but has less depth in the lower country, where Boulder empties into Turner Creek. The bed rock is calcareous schists and limestones, with some beds of graphitic schists, whose relations to the other schists were not determined. The rocks are deeply covered with moss, muck, and gravel, so that they are exposed only in mining excavations. Gold in paying quantities was discovered on Boulder Creek early in the summer of 1901. Twenty claims have been staked on the creek, all of which are reported to show colors of gold. Sluicing was begun on the creek about August 8, and some gold had been taken out with the rockers previous to that time. At the time of the writer's visit mining was in progress on claims between 3 and 7, and development work, consisting of stripping off the moss and muck, had been done on several others. On a claim about 1½ miles from the mouth of the creek both sluicing and rocking were in progress. About 2½ feet of moss and muck had been removed, exposing gravel consisting of angular fragments of graphitic schist and limestone. The gravel is reported to carry pay at this place to a depth of 4 or 5 feet, below which it has not been tested, owing to the frozen ground. A width of 56 feet of pay gravel has been uncovered. Good prospects are reported to have been found in test pits 100 feet or more from the creek bed, indicating a greater width for the pay streak. About three-fourths of a mile above this mine a prospect hole through the gravel to a depth of 11 feet failed to reach solid bed rock. The gravel there consisted mainly of limestone pebbles. Although the surface covering of moss and muck had been removed, the pay gravel below it was still frozen in September. A layer of pay dirt a few inches thick thawed each day, and was shoveled into sluice boxes and rockers. The whole area that has been worked on the creek if put together would not exceed 100 feet square. The gold is comparatively coarse, as nuggets from 25 cents up are not uncommon. These are usually rounded and dark colored. The largest nugget so far taken weighed over two ounces and was valued at $36. It was a well-rounded piece of gold, stained with iron. Mr. A. D. Nash, who controlled the freighting on the Noxapaga River and handled most of the gold from the creek, estimated that the creek produced $7,000 during the season of 1901.

At the time of the writer's visit, in September, Boulder Creek carried a volume of water sufficient to run several sluice boxes. It will probably carry

sufficient water for sluicing in all ordinary seasons. Should hydraulic methods be adopted on this creek, water can probably be brought from Turner Creek in a ditch not over 5 miles in length.

Near the Noxapaga, at the mouth of Turner Creek, a low, round hill, about 50 feet high, rises above the level of the lowland. This low butte is similar in form to many others scattered over the lowland, and is the remnant of an upper gravel plain which has in part been removed by erosion. The edge of the upper plain is usually marked by a sharply cut escarpment, from which partly isolated points often project, showing the phases of transition between the isolated butte and the continuous gravel plain. The butte near Noxapaga consists mainly of a dark deposit of impure peat mixed with layers of white sand. The peat contains trunks, bark, and limbs of spruce trees. The smaller branches are flattened by pressure of overlying gravels. The layers of white sand resemble sea-beach deposits, and suggest a driftwood origin for the peat. There is no spruce timber at present growing within the drainage of the Kuzitrin and Noxapaga rivers. At the time of this deposition, however, the climate here was undoubtedly milder, as is evidenced by the remains of the elephant and horse found in gravels of this period. At the base of the coal butte there is a large mineral spring from which carbonic acid escapes. The water is cold and resembles in taste that of soda springs, but no sample was taken for analysis. There is no connection between the spring and the coal butte, and their proximity is accidental. The peat has been tried with some success as fuel for steam thawers, and the butte is staked as a coal mine. It may prove of some importance in the development of the mines of the vicinity.

A number of creeks enter the Noxapaga River from the north, parallel to Turner and Bowlder creeks. These have been staked generally, and to some extent prospected. So far as is known to the writer, no mining has been done on any of them, with the exception of Goose Creek, a small tributary of the Noxapaga, 4 miles above Turner Creek. One man is reported to have mined continuously through the season on this creek. The writer was not able to visit the mines, and is indebted for his information in regard to the region to Mr. Lars Gunderson, recorder of the district. There is only one claim of importance on the creek. This claim was worked continuously, but the amount of gold obtained is not known. The bed rock is mica-schist and limestone.

East of Goose Creek the region between the Noxapaga and Kuzitrin rivers is reported to be covered with lava. This lava flow extends down to the Noxapaga River, and is found on the north side of the river at a point about midway between Noxapaga and Goose Creek. At this point the lava overlies the Pleistocene gravels, which here overlie mica-schists exposed in the river banks.

*Southern tributaries of the Kuzitrin.*—The creeks flowing into the Kuzitrin from the south side have not produced gold in commercial quantities; however, the writer was informed by a prospector that on Birch Creek some sluicing has been done. The pay gravel consisted mainly of decomposed granite, and the bed rock was also granite. The gold is probably derived from the rocks of the Kigluaik series. The mountains of the Bendeleben group are less rugged than the Kigluaik Mountains, and there has been little, if any, glacial erosion in them. If gold occurs in these rocks it is more likely to be concentrated in the gravels of the Bendeleben Range than in those of the Kigluaik Mountains.

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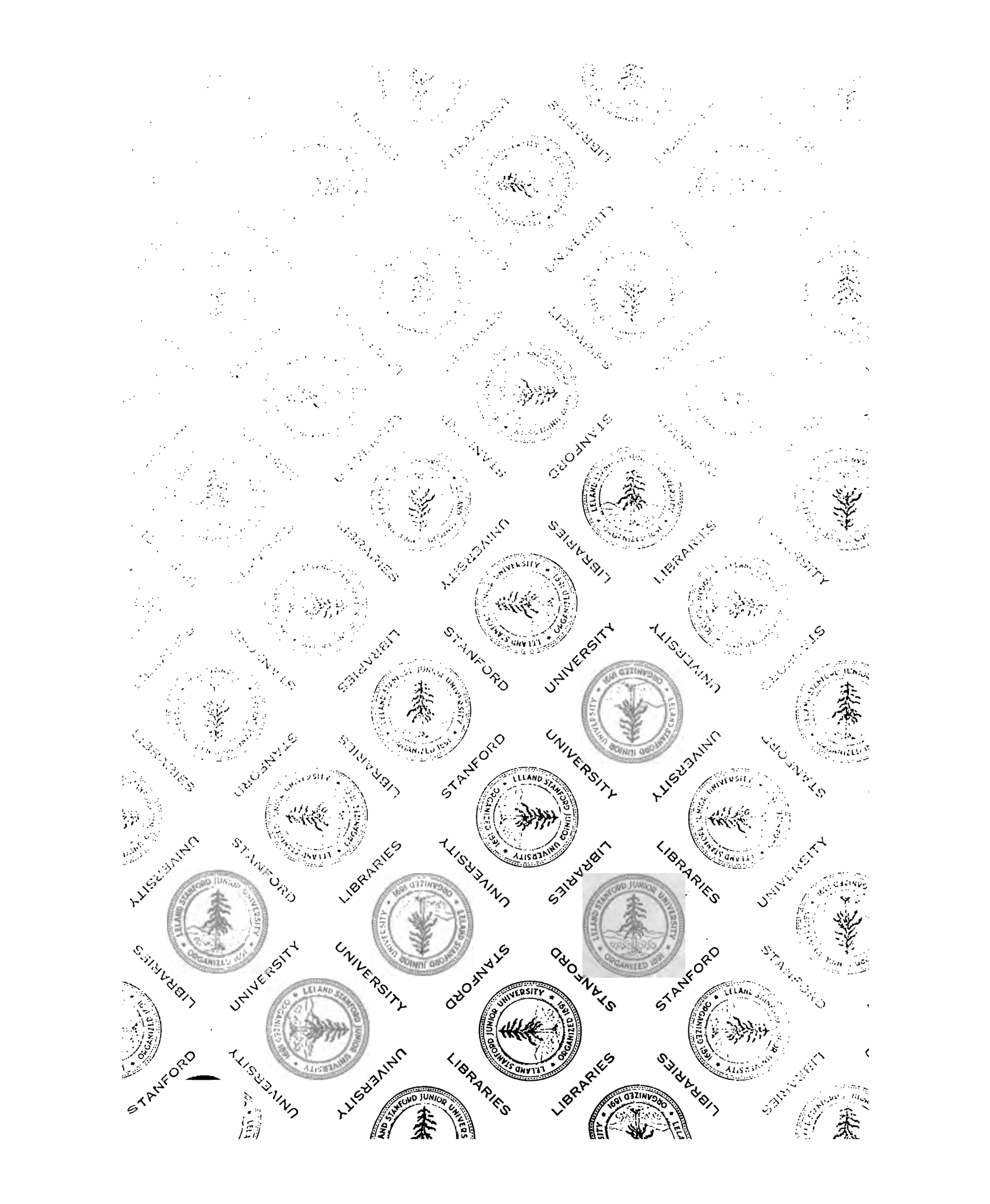
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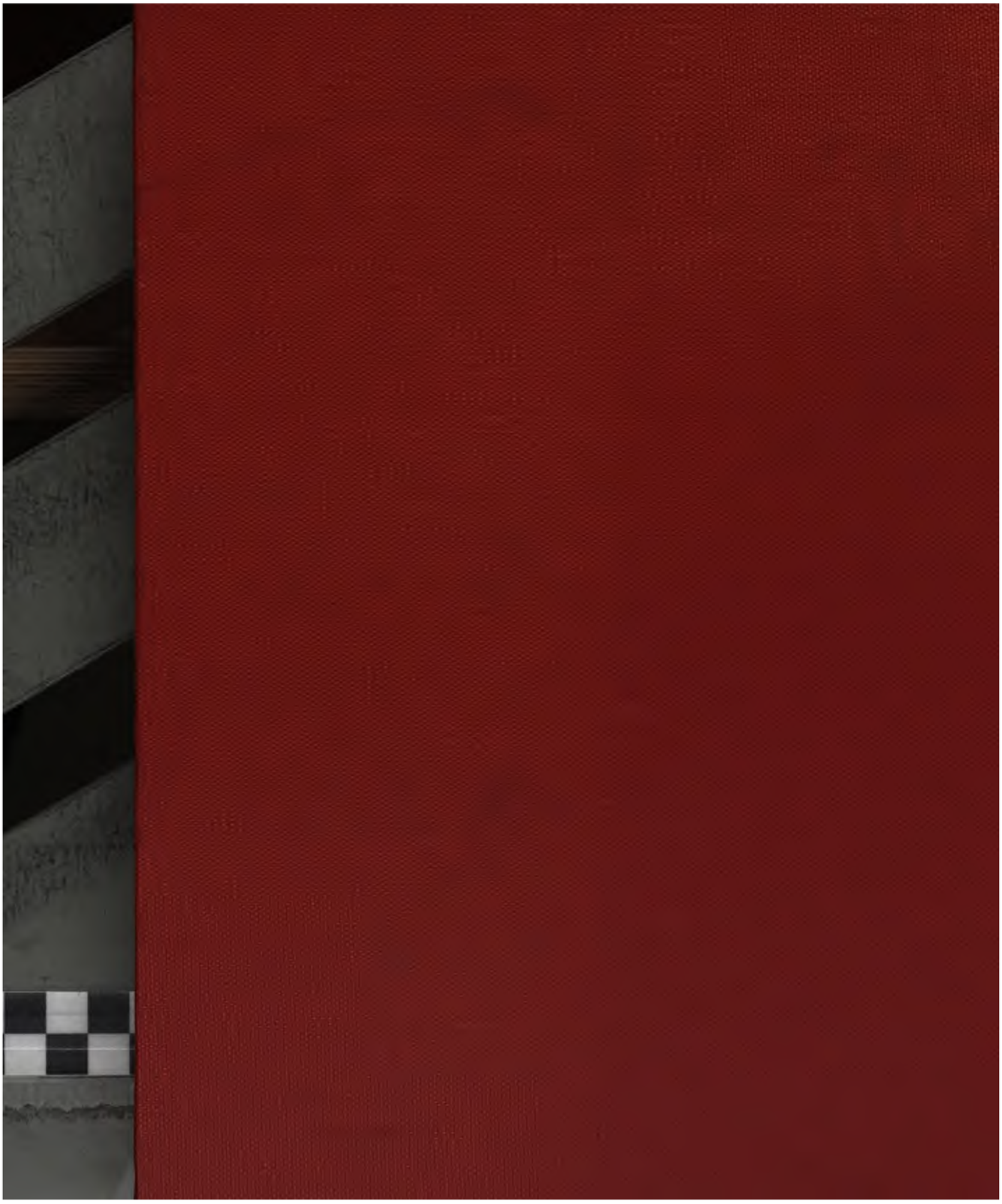
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